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Neuroimaging of temporomandibular disorders (a clinical case)

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This study adds information about the neural mechanisms underlying temporomandibular disorders (TMD) using structural and functional magnetic resonance imaging (MRI, fMRI). The aim was to analyse the relationship between the functional state of the brain and pathological changes in the joint. The study included a comprehensive clinical and instrumental examination, which included the registration of the central ratio of the jaws after using the Kois deprogrammer, as well as the use of fMRI data processing methods followed by statistical and cluster processing of the results. Structural MRI revealed degenerative changes in the temporomandibular joint (TMJ), such as articular disc displacement, degeneration and soft tissue edema. fMRI revealed activation of brain regions associated with motor control and sensory feedback, specifically in the precentral and postcentral gyrus (Brodmann area 6, 3, 43) and insular crust (Brodmann area 13). The results of the comparative analysis proved a correlation between the functional state of the brain and pathological changes in the joint, which indicates the presence of compensatory mechanisms of the central nervous system. The results demonstrate the importance of an integrated approach to the treatment of patients with TMD using modern diagnostic methods. Thus, the results of the clinical case confirm the effectiveness of using neuroimaging techniques to diagnose the central mechanisms of TMJ function regulation, open up prospects for further research in this area, and provide an example of processing data in patients with TMD. Determining changes in brain activity could help provide a more accurate assessment of the effectiveness of therapeutic interventions and improve the prognosis of the disease. Further research may be aimed at developing personalized approaches to the treatment of TMD, taking into account the individual characteristics of brain activity.

Keywords: temporomandibular joints; magnetic resonance imaging of temporomandibular joints; functional magnetic resonance imaging; neuroimaging.

Introduction

Globally, approximately 33% of the population exhibit at least one symptom of TMD, and 3.6 to 7.0% require immediate treatment (Rahimi et al., 2012). In addition, a correlation has been established between disorders of the occlusive-articulatory balance and pain manifestations, Zhehulovych et al., (2022), Dmytrenko et al., (2023). TMD is a common dental problem, encompassing all elements of the dentoalveolar apparatus. Taking into account the complexity of diagnosis and the large variability between clinical manifestations of TMD, the correlation between clinical manifestations and the results of magnetic resonance imaging of the temporomandibular joint (MRI TMJ) is according to Willkers & Katzberg (1989) – 83%, Higuchi (2019) and Tallents (2020) – 93%, Wang (2022) – 100%. Today, MRI TMJ is the standard in the diagnosis and treatment (Medaglia et al., 2019; Gharavi et al., 2022; Zieliński et al., 2023). There is a small number of literature sources indicating the feasibility of MRI examinations for planning, monitoring and evaluating dental rehabilitation, which is often a complex multi-stage process with the participation of related specialists. Initially, it was believed that chronic pain associated with TMD was primarily caused by peripheral factors, such as chronic inflammatory and/or degenerative processes in the TMJ, microtrauma of the masticatory muscles. However, the correlation between the severity of pain and tissue pathology is often weak, and not all patients clearly identify peripheral etiological factors (Yin et al., 2020; Festa et al., 2021). A few studies (Chen et al., 2022; Ito et al., 2023) found a correlation between central nervous system activity and pain, which often occurs in patients with TMD, which complicates differential diagnosis with other non-dental diseases. Functional magnetic resonance imaging (fMRI) allows non-invasive imaging of different areas of the brain depending on the goals and objectives set by the researcher (Yin et al., 2020; Van der Watt et al., 2024). A significant number of theses have been conducted by studying brain activity during mandibular movements such as chewing, swallowing, pathological movements of the lower jaw (Boillat et al., 2020; Yin et al., 2020; Wu et al., 2023). The results of fMRI are interpreted using brain atlases. The most common of all atlases to date is the Talairach Daemon label (Lacadie et al., 2008), which was used to interpret the data and further analysis. The purpose of this study was to study neuroimaging in patients with temporomandibular joint disorders.

Materials and methods

For this study, the following inclusion and exclusion criteria for selection were selected, which were approved by the protocol of the Commission on Ethics and Academic Integrity of the Shupyk National University of Health of Ukraine (Protocol No. 13/10). The purpose of this is to ensure the protection of the rights of potential participants in clinical, experimental and biomedical research with human participation or with the involvement of experimental animals, the use of microorganisms, information bases with regulated access, etc., consistent with existing international and national criteria, as well as to prevent violations of the ethics of scientific research (falsification or fabrication of empirical data, plagiarism, evaluation of empirical data using inadequate or knowingly manipulative algorithms of statistical analysis, etc.), compliance with the principles of academic integrity, moral and ethical norms and standards of behavior of researchers in the relevant field.

A 47-year-old patient turned to the Department of Prosthodontic, Digital Technologies and Implantology, Faculty of Dentistry, Shupyk National Healthcare University of Ukraine with complaints of pain in the TMJ area, expressed during movements of the lower jaw, the pain radiated to the temple zone and upper part of the head, the existing conclusion of a neurologist did not reveal signs of mental or neurological disorders.

Clinical and laboratory examinations were carried out at the Department of Prostodontic, Digital Technologies and Implantology, Faculty of Dentistry of the Shupyk National Healthcare University, magnetic resonance imaging and laboratory examinations were carried out on the basis of the radiological department of the National Children's Specialized Hospital "Okhmatdyt" of the Ministry of Health of Ukraine. During the first stage of the study, the following procedures were conducted: statement of complaint, clinical examination of the patient, questionnaires, instrumental and additional examination methods. By the results of clinical analysis and questionnaires, an instrumental examination of the patient was performed: taking alginate impressions for control and diagnostic models. Registration of central occlusion (CO), registration of the posterior contact position (PCP, aka reference position – RP, according to Slavicek & Sato (2008), was carried out using a wax plate and aluminum wax. Registration of the central jaw ratio was carried out after deprogramming of the masticatory muscles using the Kois deprogrammer (Revilla-León et al., 2024), which was used by the patient after MRI of the temporomandibular joint (TMJ) and functional MRI (fMRI). A step-by-step application of the middle anatomical and kinetic facial arches (with the determination of the patient's hinge axis) was performed for further diagnosis in the articulator.

When conducting a functional MRI examination of the brain, a block design of the study was used, according to which the "rest-task" paradigm was developed. At well-defined repetitive intervals after a period of rest, the patient was offered a stimulus "task" involving the closure of teeth in habitual occlusion. During fMRI, data were obtained on areas of the brain with increased blood flow, followed by mathematical computer processing of data and superimposition of activation maps on anatomical T1-weighted MRI images of the brain. The data obtained were analyzed on the basis of the Brodmann (1909) area scheme (Fig. 1), as well as the Talairach Daemon label.

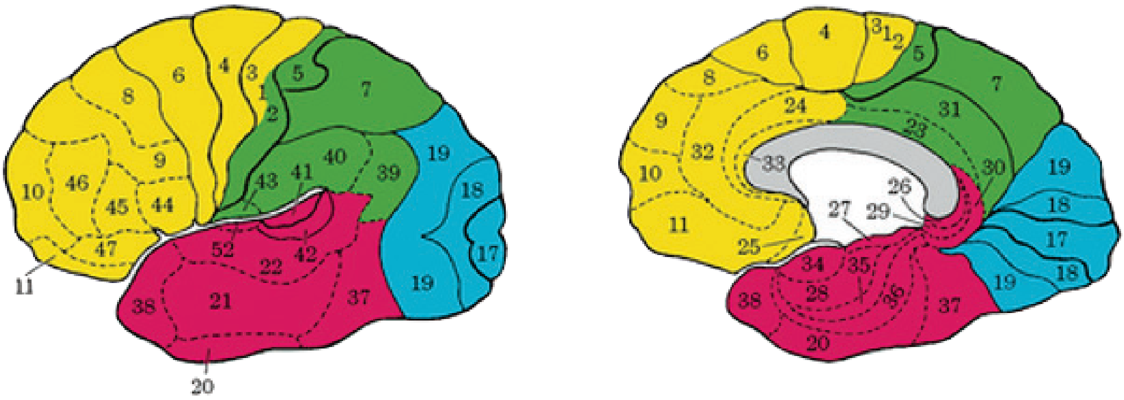

Fig. 1. The Brodmann areas proposed by Brodmann (1909)

Horos and FSL software version 6.0.1 were used to process and visualize fMRI data (Chen et al., 2022). Data Preprocessing: FSL includes tools for motion correction, alignment, tissue segmentation, and normalization of MRI data. Functional MRI Analysis (fMRI): FSL provides time-series modeling techniques in fMRI data, including standard methods for performing statistical analysis of brain activation. Structural MRI Analysis: FSL has tools for structural MRI analysis, including tissue segmentation, brain shape modeling, and other anatomical data analysis techniques. Diffusion MRI (dMRI): FSL contains tools for diffusion MRI analysis, including diffusion direction estimation, image alignment, and diffusion tensor modeling. Data visualization and interaction: FSL provides tools for visualizing MRI analysis results and interacting with data in three-dimensional space. The Dcm2niix – dcm2niix converter is designed to convert neuroimaging data from the DICOM format to the NIfTI format.

Results

Results of MRI-TMJ study. According to the results of the MRI examination, we obtained the following changes in the physiological state: Bilaminar zone of the right TMJ – moderate degeneration, damage to individual fibers of the posterior discal-ligamentous complex, more pronounced in the lateral sections, with moderate edema of the posterior space. Left articular disc – deformed at the lateral pole, unevenly shifted forward with rotation in the lateral sections, with widespread degeneration in the posterior thickening and intermediate indentation. Fibrosis and edema of the right lateral pterygoid muscle near fixation to the head and capsular discal complex in the lateral parts of the right TMJ. Minimal swelling of the left lateral pterygoid muscle near fixation to the head and the capsulardiscal complex in the lateral sections. The general conclusion of the radiologist is an uneven anterior dislocation of the right articular disc with rotation at the lateral pole bilaterally, with a decrease in the open position bilaterally, degeneration bilaminar zone and articular disc of the right TMJ, moderate hypomobility of the right TMJ. Disorganization and edema of the lateral pterygoid muscle, moderate degeneration of the articular disc of the left TMJ (Fig. 2).

Table 1
Comparative of active zones in the right and left hemispheres before treatment (explanation in text)

Right hemispheres	Brodmann areas	Left hemispheres	Brodmann areas
Frontal lobe	9, 10, 46, 45, 43	Frontal lobe	10, 44, 4, 47
Parietal lobe	52, 37, 30	Parietal lobe	2
Temporal lobe	5	Temporal lobe	21

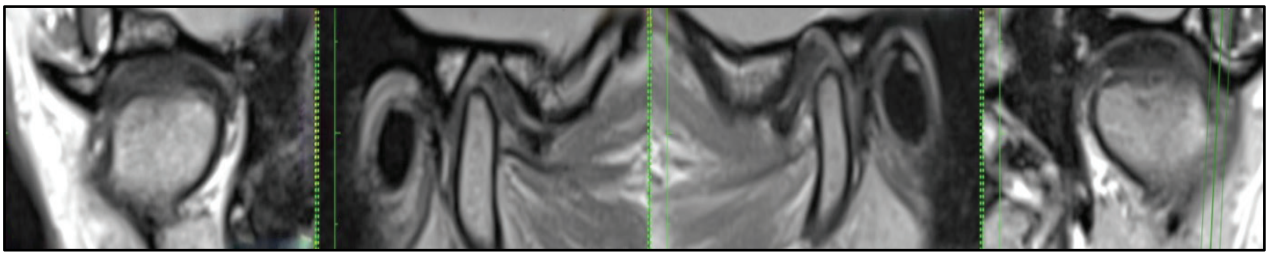

Fig. 2. Results of the MRI examination of the TMJ (parasagittal and paracoronal projection of the medial pole, explanation in text)

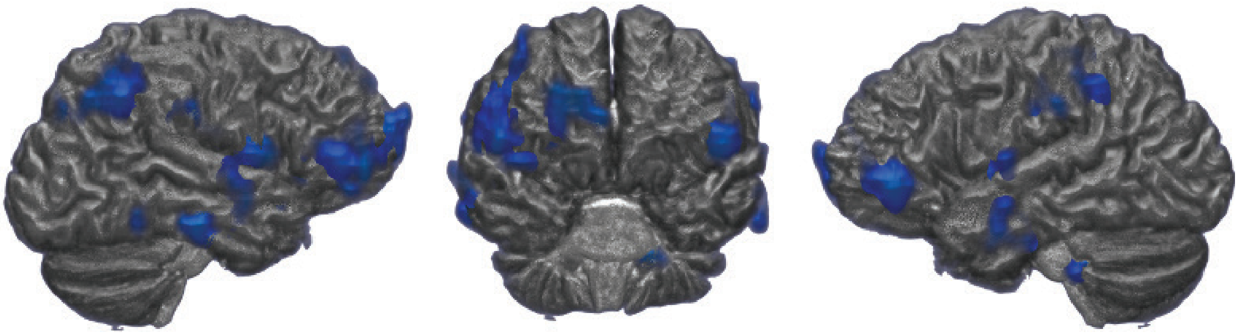

Fig. 3. Neuroimaging of the brain before treatment (blue highlights areas of activation obtained as a result of neuroimaging, explanation in text)

Results of fMRI examination. Activity in subsequent areas of the cerebral cortex, according to Brodmann's zones, was noted in a state of usual occlusion (Fig. 3, Table 1). According to the cytoarchitectonic map of the cerebral cortex, there is a marked activation of the frontal lobes of the brain, especially the prefrontal cortex. Particular attention is paid to the anterior cingulate cortex, where the center for pain perception and the center for monitoring conflicts and errors are located. This indicates the "intensity" of central adaptive mechanisms, possibly associated with the implementation of the efferent component of the elimination of pathobiomechanical disorders of the TMJ.

The statistical processing of the obtained data gave the following results: standard deviation of the population (σ): 0.3517, standard deviation of the sample (S): 0.3563, range: from 3.59 to 4.96, logistic regression indicated the accuracy of the model at the level of 72.7%. The results of the logistic analysis indicated the value of the area under the curve (AUC) = 0.80, which indicates a good ability of the model to distinguish between high and low activation (Fig. 4).

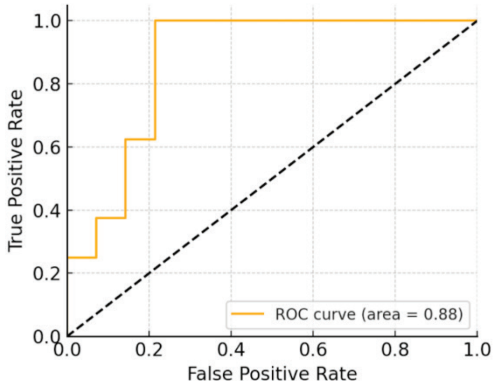

Fig. 4. Receiver operating characteristic of the obtained data

The Talairach Daemon Atlas presents the coordinates of brain regions obtained by fMRI and their correspondence to regions, a database used to identify anatomical regions in brain images. The table states: A task is a task or experimental state in which certain areas of the brain have been activated. A region is an anatomical region of the brain that has shown activation or changes in activity. The activation index is the strength of activation or an index that can correspond to statistical significance or intensity. Right hemisphere / Left hemisphere are Talairach coordinates that indicate the position of an area in the right or left hemisphere of the brain. Result of a comparative fMRI result (BOLD) using the Talairach Daemon Atlas: the data obtained were then entered into a table and the statistical data was determined (Table 2).

The fMRI (BOLD) analysis revealed significant activation in several key brain regions during jaw clenching compared to the relaxed jaw position, reflecting the integration of motor control, sensory processing, and cognitive engagement. The highest activation was observed in the right cerebrum, limbic lobe, anterior cingulate gray matter (Brodmann area 10, Z-MAX = 5.78, P < 0.0001, 6022 voxels, MNI: 7, 58, -9), indicating its involvement in pain regulation and cognitive control of movement. Significant activation was also found in the left cerebrum, frontal lobe, middle frontal gyrus (white matter, Z-MAX = 5.54, P < 0.0001, 5143 voxels, MNI: -42, 42, -10), suggesting the role of frontal regions in movement planning and cognitive modulation of masticatory functions. The right cerebrum, sub-lobar, insula (Z-MAX = 5.26, P < 0.0001, 5084 voxels, MNI: 52, 4, 1) exhibited a high level of activation, likely reflecting somatosensory integration and pain perception. Additional activation in the right cerebrum, frontal lobe, inferior frontal gyrus (Z-MAX = 4.92, P < 0.0001, 2364 voxels, MNI: 55, 51, -5) supports the role of this area in motor control and sensory feedback during jaw movement. The involvement of the left cerebrum, parietal lobe, inferior parietal lobule (Z-MAX = 4.77, P < 0.0001, 3403 voxels, MNI: -60, -32, 26) indicates the processing of proprioceptive information from the masticatory system, while the right cerebrum, temporal lobe, inferior temporal gyrus (Z-MAX = 4.47, P = 0.003, 1545 voxels, MNI: 69, -4, -21) suggests participation in sensorimotor integration. Furthermore, the activation of the right cerebrum, occipital lobe, middle occipital gyrus (Brodmann area 19, Z-MAX = 4.47, P = 0.008, 1267 voxels, MNI: 38, -92, 23) implies a possible role in visuospatial orientation during motor execution. Significant changes were also found in the right cerebrum, temporal lobe, superior temporal gyrus (white matter Z-MAX = 4.46, P = 0.003, 1524 voxels, MNI: 44, 7, -31), potentially related to auditory processing or sensory feedback integration. Notably, substantial activation in the right cerebellum, posterior lobe, tuber gray matter (Z-MAX = 4.38, P = 0.007, 1333 voxels, MNI: 57, -50, -31) reflects its coordinative function in jaw movement, whereas the right cerebellum, parietal lobe, inferior parietal lobule (Z-MAX = 4.28, P = 0.001, 2052 voxels, MNI: 69, -29, 28) confirms its role in controlling jaw position. The final significant activation was observed in the right cerebrum, sub-lobar, extra-nuclear white matter (Z-MAX = 4.15, P = 0.008, 1248 voxels, MNI: 31, -6, -14), suggesting involvement of subcortical sensorimotor pathways. These findings confirm the high degree of interaction between sensorimotor, limbic, and cognitive systems of the brain during jaw clenching, which is critical for understanding the neural mechanisms of masticatory function regulation and pain-related conditions associated with temporomandibular joint dysfunction.

During hierarchical clustering of the obtained data (by clustering – Ward binding), clearly defined groups were identified, where regions with similar index values were grouped together. The first cluster includes 26 regions, mainly located in the frontal and parietal lobes of both hemispheres, with an average index of 3.84 (range 3.59–4.08), which may indicate their role in motor control and sensory integration. The second cluster contains 13 regions, mostly temporal and limbic lobes, with an average index of 4.47 (range 4.16–4.96), suggesting their likely involvement in cognitive and emotional processes. The distribution by hemispheres showed that most of the zones of the first cluster belong to the right hemisphere, while in the second cluster there is a more uniform distribution between the left and right sides.

According to the analysis of threshold results (Current silhouette coefficient 1.5), two main clusters were identified. At the same time, using the silhouette method (the value of the silhouette coefficient is 0.638), we kept 4 clusters, since such a distribution of zones by groups is more adequate.The use of this coefficient is justified by the balance between the clarity of clustering and the flexibility of analysis, since the value of 0.638 is the optimal compromise between the quality of grouping and the number of clusters, which avoids excessive data division or loss of important information (Fig. 5).

Table 2
fMRI (BOLD) results

Anatomical region	Activation index (AI) Z-MAX	Corrected *p* value, whole cluster -ln(P)	Number of voxels in cluster	False Discovery rate-corrected *p* value of voxel	Uncorrected, *P* value voxel	Talairach Daemon Atlas Coordinates mni (x,y,z)		
Right Cerebrum. Limbic Lobe. Anterior Cingulate Gray Matter. Brodmann area 10	5.78	8.63	6022.0	0.000	0.000	7	58	–9
Left Cerebrum. Frontal Lobe Middle Frontal Gyrus White Matter	5.54	7.65	5143.0	0.000	0.000	–42	42	–10
Right Cerebrum. Sub-lobar Insula	5.26	7.6	5084.0	0.000	0.000	52	4	1
Right Cerebrum. Frontal Lobe Inferior Frontal Gyrus	4.92	3.97	2364.0	0.000	0.000	55	51	–5
Left Cerebrum. Parietal Lobe Inferior Parietal Lobule	4.77	5.47	3403.0	0.000	0.000	–60	–32	26
Right Cerebrum. Temporal Lobe Inferior Temporal Gyrus	4.47	2.63	1545.0	0.003	0.002	69	–4	–21
Right Cerebrum. Occipital Lobe Middle Occipital Gyrus Gray Matter Brodmann area 19	4.47	2.12	1267.0	0.008	0.008	38	–92	23
Right Cerebrum. Temporal Lobe Superior Temporal Gyrus White Matter	4.46	2.59	1524.0	0.003	0.003	44	7	–31
Right Cerebellum. Posterior Lobe Tuber Gray Matter	4.38	2.24	1333.0	0.007	0.006	57	–50	–31
Right Cerebrum. Parietal Lobe Inferior Parietal Lobule	4.28	3.48	2052.0	0.001	0.000	69	–29	28
Right Cerebrum. Sub-lobar Extra-Nuclear White Matter	4.15	2.08	1248.0	0.008	0.008	31	–6	–14

Notes: activation index (AI) – refers to a measure of the level of neural activation in a specific area of the brain, derived from the level of oxygen in the blood (BOLD) signal, which indicates changes in blood flow and oxygen saturation associated with neural activity; coordinate (x, y, z) this refers to the spatial arrangement of voxels (volumetric pixels) in the brain; these coordinates are used in BOLD (blood oxygenation level); the signal measures the brain where neural activity is detected; x (left-right): this axis usually represents the lateral dimension, with negative values pointing to the left side of the brain and positive values pointing to the right side, y (anterior-posterior): this axis corresponds to the dimensions anterior-posterior; positive values usually represent the front (frontal) part of the brain, while negative values represent the back (back) part; z (Lower-upper): the z-axis corresponds to the height or vertical dimension; positive values usually indicate an upper (higher or closer to the top) location in the brain, while negative values indicate lower (below or closer to the base); "–" no activation level was identified within the threshholding

As a result of using the value of the silhouette coefficient of 0.638, the following zones were included in Cluster 1 (orange) (Fig. 5): the next zones were included: left cerebrum parietal lobe postcentral gyrus gray matter Brodmann area 3, left cerebrum parietal lobe postcentral gyrus gray matter Brodmann area 43, right cerebrum frontal lobe precentral gyrus white matter, left cerebrum frontal lobe precentral gyrus gray matter Brodmann area 6, left cerebrum sub-lobar insula gray matter Brodmann area 13. To Cluster 2 (red): right cerebrum limbic lobe cingulate gyrus white matter, left cerebrum frontal lobe middle frontal gyrus white matter.

Discussion

Our neuroimaging results demonstrate a clear correlation between structural changes in the temporomandibular joint (TMJ) and the functional activity of the corresponding brain regions. In particular, significant degenerative lesions of the right TMJ were associated with increased activation in contralateral (left hemisphere) cortical zones such as the precentral gyrus (Brodmann, 1909), which is responsible for motor control, and the insular cortex, which provides somatosensory integration (Geyer et al., 2011). At the same time, less pronounced changes in the left TMJ correlated with a reduced level of activation of the motor zones of the right hemisphere, reflecting a lower need for neurocompensation (Chen et al., 2022).

The findings are consistent with previous studies (Geyer et al., 2011; Boillat et al., 2020; Chen et al., 2022), which indicate involvement of the sensorimotor cortex, insular region, and cingulate gyrus in patients with TMD. Functional neuroimaging tests with jaw clenching or pain stimulation in temporomandibular disorders (TMD) have shown activation of motor areas and pain processing centers such as the anterior cingulate cortex described in the Chen study (Chen et al., 2022). In addition, a study using fMRI resting states demonstrated dysregulation of activity in the sensorimotor network and pain-related areas in patients with chronic TMJ disorders (Yin et al., 2020). A few authors note that in patients with TMJ pathology, additional areas of the brain are involved in maintaining function - in particular, there is an increased activation of the motor cortex as a compensation for weakened chewing function (Festa, Rotelli, Scarano et al., 2021). The pronounced activation of the anterior cingulate cortex (ACC), recorded in our case, indicates intense central modulation of pain and motor control, which is confirmed by the findings of Wang et al., 2022. In general, these neuroimaging data support current scientific ideas about the important role of central mechanisms in the development of temporomandibular disorders (Kuć et al., 2019; Yin et al., 2020; Festa et al., 2021; Chen et al., 2022; Van der Watt et al., 2024). The correlation between structural changes in the joint and the functional activity of the brain indicates a close relationship between peripheral and central neurophysiological processes (Revilla-León et al., 2024).

A similar interdependence has been noted by other researchers: in particular, Yin et al. (2020) reported a link between joint tissue pathology and brain activity, Festa et al. (2021) confirmed the effectiveness of fMRI for assessing central adaptive changes in TMD. Our work complements this data by providing a clinical case that directly demonstrates parallel structural and functional changes in TMD. The presence of pronounced compensatory mechanisms of the central nervous system and neuroplasticity is of great interest among scientists and has important implications for a deeper understanding of nervous regulation in the chronic TMD. Brain neuroplasticity means that effective therapy of TMJ patients should be aimed not only at eliminating local joint pathology or occlusion, but also at normalizing altered brain activity (Boillat et al., 2020). It is significant that after successful occlusive treatment and pain reduction, a significant attenuation of abnormal activation of pain neural networks was recorded in patients with TMD, despite the absence of changes in the joint structure (Kuć et al., 2019; Yin et al., 2020; Festa et al., 2021). This suggests that therapeutic measures can exploit CNS plasticity to alleviate symptoms.

Moreover, some interventions targeting the central nervous system (e.g., non-invasive stimulation of the motor cortex) are able to reduce chronic pain by restoring normal functional activity of the motor cortex (Kuć et al., 2019). The use of neuroimaging as a tool for monitoring and optimizing therapy in the future is promising. Functional MRI using standard brain atlases provides objective markers of changes in the CNS, which allows us to assess the extent to which therapeutic interventions affect adaptive central mechanisms (Boillat et al., 2020). Additionally, modern data processing methods (such as cluster analysis) make it possible to identify specific patterns of brain activation that can serve as potential biomarkers of the effectiveness of occlusive therapy. The use of this research method is also likely to allow one, under the control of changes in jaw position, to assess the effectiveness of TMD therapy, as well as theoretically carry out a prognostic model. The results of our study confirm current scientific ideas about the importance of central mechanisms in the development of TMD (Tamimi et al., 2019; Higuchi et al., 2020). The revealed correlation between structural changes in the TMJ and the functional activity of the brain indicates a close relationship between peripheral and central neurophysiological mechanisms (Chen et al., 2022). It is important to note that fMRI data, in particular the use of the Talairach atlas, can be an objective tool for assessing the effectiveness of therapeutic interventions, allowing for individualization of the approach to patient treatment. More research is needed to better understand the mechanisms of central compensation and the development of neuroplasticity.

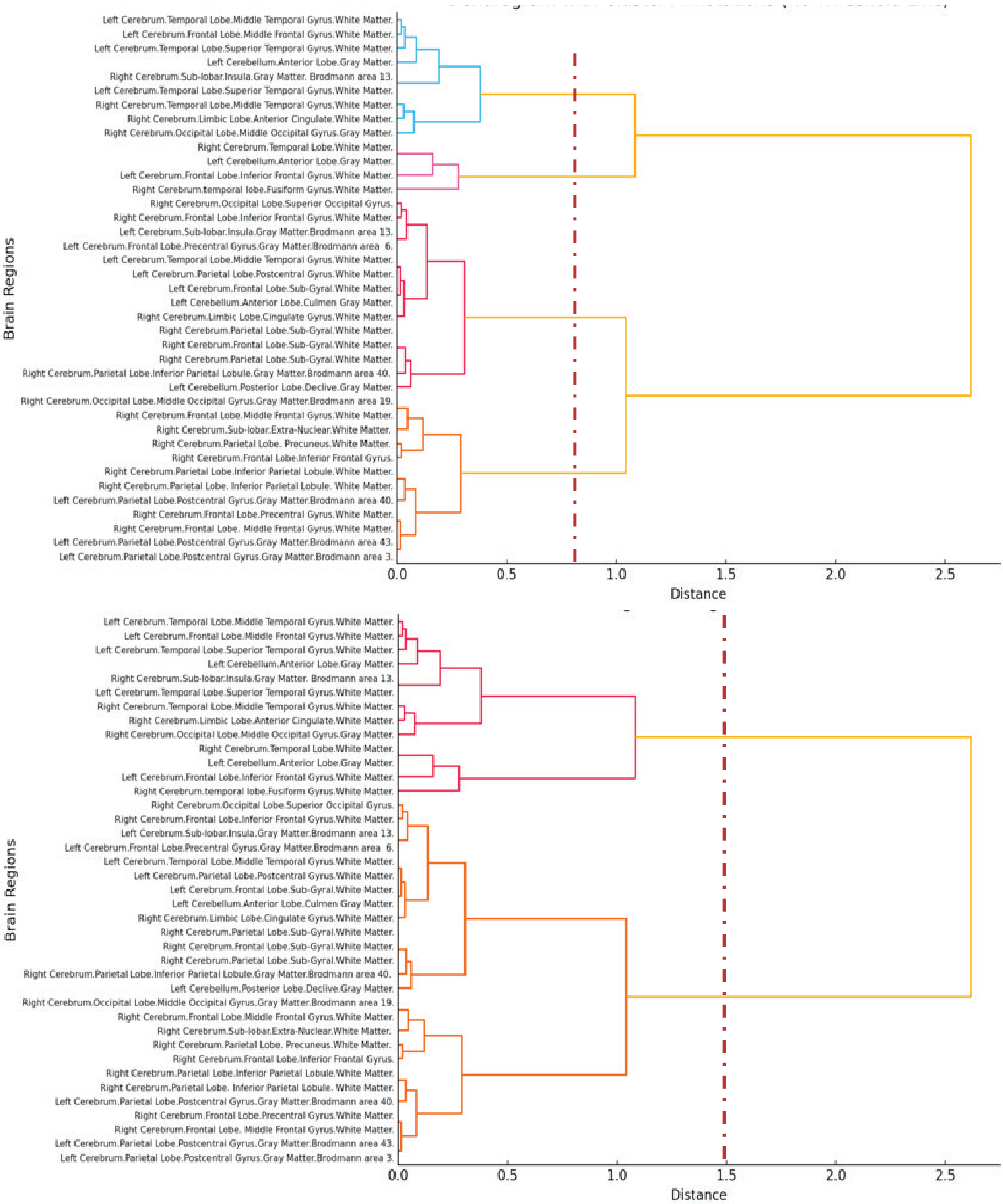

Fig. 5. Hierarchical clustering dendogram of brain regions with different silhouette coefficient (left – 1.500, right 0.638)

Further use of fMRI cluster analysis will identify specific activation patterns that can serve as biomarkers of the effectiveness of occlusive therapy. Thus, the results of the clinical case confirm the effectiveness of using neuroimaging techniques to assess the state of central mechanisms of TMJ function regulation and open up prospects for further research in this area. Further study of central compensatory processes in TMD will deepen the understanding of the pathophysiology of this disorder and contribute to the development of more effective, individualized approaches to the treatment of patients with TMD.

Conclusion

Analysis of the correlation between the results of magnetic resonance imaging of the temporomandibular joint (TMJ MRI) and functional MRI (fMRI) of the brain demonstrates the relationship between structural changes in the joints and the functional activity of the brain, which corresponds to the generally accepted principles of somatotopic organization of the motor cortex. It was found that in patients with TMD in fMRI, there is an increased activation in the motor and sensory areas of the corresponding contralateral hemispheres, in particular: precentral gyrus (Brodmann area 6) – planning and execution of movements, postcentral gyrus (Brodmann area 3, 43) – processing of sensory information, insular cortex (Brodmann area 13) – integration of somatosensory sensations. These results confirm that fMRI can be an effective tool for detecting neuroplastic changes in the CNS in TMD caused by existing orthodontic pathology or occlusive disorders.

The results of statistical analysis of fMRI showed a significant difference between the activity of TMD-associated regions during the rest-occlusion task. Variance analysis (ANOVA) revealed a high level of significance ($P < 0.05$), which confirms the presence of differences in neural activity between groups of patients, and is built into the paradigm of this study. Reducing the complexity of data interpretation – fMRI generates a large amount of data, clustering helps to identify the most relevant patterns, a deeper understanding of TMD mechanisms, allowing patients to be classified by the type of neural response, identifying new connections between regions that may not be obvious in traditional analysis. Therefore, cluster analysis is an appropriate tool for a deeper understanding of functional changes in the brain of patients with TMJ p.

With the help of cluster analysis, four main groups of regions were identified that demonstrate similar activation patterns. When using a silhouette coefficient of 0.638, a moderately strong cluster structure was revealed, which indicates an adequate distribution of zones into groups. The use of this coefficient is justified by the balance between the clarity of clustering and the flexibility of analysis, since the value of 0.638 is the optimal compromise between the quality of grouping and the number of clusters, which avoids excessive data separation or loss of important information for the analysis of fMRI data. The results of the cluster analysis clearly identified a group of regions involved in the control of mandibular movements, including: precentral gyrus (Brodmann area 6) – generation of motor commands, postcentral gyrus (Brodmann area 3, 43) – sensory feedback processing, insular cortex (Brodmann area 13) – integration of motor and sensory functions. Understanding functional activity allows for personalization of rehabilitation strategies for patients with TMD, focusing on correcting the activity of certain brain structures, and a better understanding of the role of related specialists for a multidisciplinary approach to treatment. Using cluster analysis the main activity was concentrated in the zones of the motor and sensorimotor cortex, which is consistent with the biomechanics of mandibular movement.

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