RESEARCH ARTICLE

Correlation between the lateral pterygoid muscle attachment type and temporomandibular joint disc position in magnetic resonance imaging

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Objectives: The aim of this study was to investigate the correlation between the lateral pterygoid muscle (LPM) attachment type and temporomandibular joint (TMJ) disc position on sagittal and coronal MR scans.

Methods: 191 patients (148 females, 43 males), aged 14–60 years, underwent MR investigations of the TMJs in the intercuspal position (IP) and open-mouth position (OMP). The disc position was evaluated on oblique sagittal and coronal images in the IP and OMP on many MRI sections showing all portions of the joint. Relationships between the LPM attachment patterns and articular disc positions were evaluated by z and χ^2 tests.

Results: Three types of the LPM attachment were found. There was a statistically significant correlation between the LPM attachment type and the disc position in IP ($\chi^2 = 24.29$; $p < 0.01$). The type of muscle attachment did not determine the prevalence of normal, lateral and medial disc positions. There were differences between the muscle attachment types in the anterior, anteromedial and anterolateral disc positions. There was a statistically significant association between TMJ disc position in OMP and particular attachment types in the sagittal plane ($\chi^2 = 9.702$; $p < 0.01$).

Conclusions: Certain types of the LPM insertion are correlated with TMJ disc position. *Dentomaxillofacial Radiology* (2016) **45**, 20160229. doi: [10.1259/dmfr.20160229](https://doi.org/10.1259/dmfr.20160229)

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Introduction

The activity of the lateral pterygoid muscle (LPM) is necessary for complex movements of the temporomandibular joint (TMJ). For many years, researchers have agreed that two separate heads—inferior and superior, form the LPM.^{1–3} However, recent literature has brought speculation and controversy on the anatomical variations of the LPM, particularly regarding the insertion into the disc–condyle complex.^{4–7} Studies on human specimens have revealed the presence of a third

head of the LPM. Moreover, from three to four different types of muscle attachment have been distinguished.^{4–8}

Currently, MRI is regarded as the gold standard for the assessment of the TMJ internal derangement in patients with temporomandibular disorders (TMD).⁹ MRI is capable of providing information on the TMJ disc position and morphology of adjacent structures without exposing patients to radiation. MRI is also used to visualize the LPM and assess its attachment types.^{6,7,10,11}

The LPM is functionally heterogeneous and its heads can exert different effects on the condyle–disc complex.^{12,13} It is hypothesized that specific attachment

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types in conjunction with the diverse functionality of this muscle may pose an anatomical predisposition for TMJ internal derangement. Some authors investigated the association between anatomical variations of the LPM attachment type and the presence of TMJ disc displacement.^{5,6,10,14} Such an association, however, has not been established.^{5–7,10} Nevertheless, studies investigating the correlation between the LPM attachment type and TMJ internal derangement analyzed the disc position only in the sagittal plane. Assessment of the disc in the sagittal plane is suitable for the diagnosis of anterior disc displacement, which is one of the most prevalent types. However, since muscle fibres of the LPM are attached to the anterior and the medial aspect of the disc–condyle complex,^{15,16} muscle fibres may tend to pull the disc in not only the sagittal, but also the coronal plane. Hence, it is our opinion that certain types of the LPM attachment may be attributed to multidirectional disc displacements and since sagittal plane imaging is often incapable of disclosing multidirectional displacements, additional coronal scans are necessary to assess fully the disc position.¹⁷ A complete assessment of the disc position in two planes is important because disc displacements in the coronal plane may also be clinically relevant.¹⁸

Therefore, we decided to test the null hypothesis that there is a correlation between the LPM attachment type and TMJ disc position, on sagittal and coronal MRI scans.

Methods and materials

Study group

The study group comprised 191 patients with TMD (148 females, 43 males) aged 14–60 years. The patients were referred to the Department of Functional Masticatory Disorders at the Medical University of Lublin for the diagnostic examination and treatment of TMD. All patients were classified according to the generally accepted diagnostic protocol RDC/TMD.¹⁹ Persons who met the criteria of Group II (disc displacements) of the mentioned classification were included into the study. Patients with a history of facial trauma, systemic inflammatory arthritis, TMJ tumour or TMJ surgery were excluded from the study. Patients underwent MRI for diagnostic purposes.

MRI

MRI investigations of the TMJs were carried out in the intercuspal position (IP) and open-mouth position (OMP) using silicon indices. All patients underwent bilateral MRI examinations of TMJs with a dedicated TMJ surface coil. MR images were obtained by means of a 1.5-T MRI unit (1.5-T Eclipse; Picker International, Inc., Cleveland, OH). Proton density, T_1 and T_2 weighted fast spin-echo images were recorded. MRI was performed in the oblique sagittal (Figure 1) and coronal (Figure 2) slices. The following image acquisition parameters were obtained for the examined

Figure 1 Oblique sagittal slices.

sagittal oblique images: repetition time = 2000 ms, echo time = 15 ms, field of view 16 cm, slice thickness = 2 mm and matrix size 256×256 pixels. For coronal images, the following image acquisition parameters were obtained: repetition time = 485 ms, echo time = 12 ms, field of view 14 cm and slice thickness 2 mm.

Evaluation of the lateral pterygoid muscle insertion type

The insertion types of the LPM were evaluated on oblique sagittal MRI scans in IP and OMP and categorized into three types (Figures 3–5), as presented in Table 1.

Evaluation of temporomandibular joint disc position

The disc position was evaluated on oblique sagittal and coronal images in the IP and OMP on many MRI sections showing all portions of the joint (Figures 1 and 2). The positions of the disc were categorized according to the literature^{9,20,21} as follows:

- normal (superior)
- anterior (anterior displacement without lateral and medial components)
- displaced simultaneously in the sagittal and coronal planes—in anterolateral or anteromedial directions

Figure 2 Oblique coronal slices.

Figure 3 (a) Type I attachment of the lateral pterygoid muscle (LPM); (b) anterior disc displacement on MRI of the temporomandibular joint (TMJ) with the Type I attachment of LPM on the selected slice in the oblique sagittal plane in intercuspal position (IP); and (c) no disc on MRI of TMJ with the Type I attachment of the LPM on the selected slice in the oblique coronal plane in IP [same joint as in (b)].

- (anterior displacement with lateral or medial component)
- displaced only in the coronal plane (pure lateral or medial disc displacement).

In joints where disc displacement was found in the oblique sagittal or coronal plane, evaluation in OMP was performed in the appropriate plane. The disc position in OMP was classified as normal (with reduction) or displaced (without reduction), respectively. Moreover, low-quality scans in the coronal plane, *i.e.* those due to patient motion, were not considered in the evaluation.

Observer calibration

Two experienced observers, with a mean of 15 years' experience in TMJ MRI scan interpretation, separately analyzed MR images. The observers were evaluated beforehand during a calibration session, at which interobserver reliability assessment revealed acceptable agreement ($\kappa = 0.78$). In cases of disagreement, the final consensus was reached through discussion.

Statistical analysis

The interobserver reliability of measurements was assessed using Cohen's kappa statistic (κ). Relationships between the LPM attachment patterns and articular

disc positions were evaluated by z and χ^2 tests. The level of significance was set at $p < 0.05$. The strength of dependency between studied variables has been evaluated by Pearson's contingency coefficient (C_{cor}). Data were analyzed using IBM SPSS® Statistics v. 20 software (IBM Corp., New York, NY; formerly SPSS Inc., Chicago, IL).

Ethical approval

The Bioethics Committee of the Medical University of Lublin, Poland, approved this study (no. KE-0254/11/2015).

Results

In the analysis of 382 MRI scans, Type I of the LPM attachment was detected in 7.6% scans, Type II in 66.7% scans and Type III in 25.7% scans (Table 2). Distribution of disc positions in IP according to the LPM attachment type is presented in Table 3.

There was a statistically significant correlation between the LPM attachment type and disc position in IP, although the strength of this dependency was weak ($\chi^2 = 24.29$; $p < 0.01$; $C_{\text{cor}} = 0.303$) (Table 3). The type of

Figure 4 (a) Type II attachment of the lateral pterygoid muscle (LPM); (b) anterior disc displacement on MRI of the temporomandibular joint (TMJ) with the Type II attachment of LPM on the selected slice in the oblique sagittal plane in intercuspal position (IP); and (c) lateral disc displacement on MRI of TMJ with the Type II attachment of LPM on the selected slice in the oblique coronal plane in IP [same joint as in (b)].

Figure 5 (a) Type III attachment of the lateral pterygoid muscle (LPM); (b) normal disc position on MRI of the temporomandibular joint (TMJ) with the Type III attachment of the LPM on the selected slice in the oblique sagittal plane in intercuspal position (IP); and (c) medial disc displacement on MRI of TMJ with the Type III attachment of LPM on the selected slice in the oblique coronal plane in IP [same joint as in (b)].

muscle attachment did not determine the prevalence of normal, lateral or medial disc positions. Nevertheless, there were differences between muscle attachment types in the anterior, anteromedial and anterolateral disc positions.

In the first type of the LPM attachment, anterior disc position was most prevalent. The presence of anterior disc position was significantly higher in Type I than in Type II ($p < 0.01$) or Type III ($p < 0.001$) of the LPM attachment.

In the second type of the LPM attachment, normal, anterior and anterolateral positions were equally prevalent and observed in about 25% of the joints. The anterolateral disc position was significantly higher than that in Type I ($p < 0.05$).

In the third type of the LPM attachment, the normal and anterolateral disc positions were most frequent (23.5 and 24.5%). The anterolateral disc position was significantly more prevalent in Type III than in Type I ($p < 0.05$). The second most prevalent disc positions in Type III muscle attachment were anterior and anteromedial (17.3%). The anteromedial disc position was significantly higher than that in Type II ($p < 0.05$).

Distribution of disc positions in OMP according to the LPM attachment type is presented in Tables 4 and 5. In OMP, there was a statistically significant association between TMJ disc position and particular types of muscle attachment in the sagittal plane ($\chi^2 = 9.702$; $p < 0.01$) (Table 4). However, the strength of this dependency was weak ($C_{cor} = 0.245$). The comparison of the presence of pathological TMJ disc position in a particular type of muscle attachment revealed that the

prevalence of disc displacement without reduction was less frequent in Type III and most frequent in Type I. Type I in comparison with Type II and III significantly correlated with TMJ disc position without reduction in OMP in the sagittal plane ($p < 0.01$ and < 0.01) (Table 4).

There was no significant correlation between the type of muscle attachment and disc position in OMP in the coronal plane ($\chi^2 = 0.135$; $p > 0.05$) (Table 5).

Discussion

The majority of authors of classic textbooks and earlier anatomical studies assert that the LPM has two heads. Some studies report the presence of a third head; yet, it is rarely described in the literature.^{5,8,22} In addition, the LPM insertion patterns are a controversial issue. Most authors agree that the lower head inserts into the condyle, but some disagree as to the attachment of the upper head.^{4,5,7} Visibility of more than two heads of LPM depends on the overall system signal, sequence protocol, slice thickness and positioning including inclination of sagittal oblique slices in relationship to condylar head axes.

The results of our study confirm that the LPM has variable attachment patterns. The MRI scans show three different types of the LPM insertion into the disc–condyle complex. Moreover, the investigation revealed the presence of a third head of the muscle in 98 (25.7%) cases. Our result corresponds to the findings of Kilic et al⁸ and Antonopoulou et al,⁴ who observed the three-headed LPM in 17 out of 32 joints and in 8 out of 36 joints, respectively. Our findings are also consistent with the study by Dergin et al,⁵ who found the third

Table 1 The insertion types of the lateral pterygoid muscle

Insertion type	Head	Insertion
Type I	Upper	Disc
	Lower	Condyle
Type II	Upper	Disc and condyle
	Lower	Condyle
Type III	Upper	Disc
	Middle	Condyle
	Lower	Condyle

Table 2 Distribution of the lateral pterygoid muscle attachment types

Type	n	%
Type I	29	7.6
Type II	255	66.7
Type III	98	25.7
Total	382	100

Table 3 Distribution of temporomandibular joint (TMJ) disc positions in intercuspal position according to the lateral pterygoid muscle (LPM) attachment type

TMJ disc position	LPM attachment type							
	I		II		III		Total	
	n	%	n	%	n	%	n	%
Normal	4	13.8	61	23.9	24	24.5	89	23.3
Anterior	16	55.2 ^{a,b}	66	25.9 ^a	17	17.3 ^b	99	25.9
Anterolateral	2	6.9 ^{c,d}	67	26.3 ^c	23	23.5 ^d	92	24.1
Anteromedial	3	10.3	23	9.0 ^e	17	17.3 ^e	43	11.3
Lateral	1	3.4	9	3.5	7	7.1	17	4.5
Medial	3	10.3	29	11.4	10	10.2	42	11.0
Total	29	100	255	100	98	100	382	100

$\chi^2 = 24.29$; $p < 0.01$; Pearson's contingency coefficient = 0.303.

^a $z = 3.22$; $p < 0.01$.

^b $z = 4.07$; $p < 0.001$.

^c $z = 2.31$; $p < 0.05$.

^d $z = 1.98$; $p < 0.05$.

^e $z = 2.24$; $p < 0.05$.

head of the LPM in 29.6% of examined joints. Pompei Filho *et al*²² analyzed the LPM insertion in 178 TMJ MRI scans and found the middle head in 20.22% of joints inserted entirely into the disc surface.

In contrast to our results, Taskaya-Yilmaz *et al*¹⁰ and Omami *et al*⁷ found only two heads of the LPM. However, their studies were based on samples smaller than that in our investigation, which may explain the different outcomes. Furthermore, the evaluation of the LPM insertion in these studies was restricted to the single sagittal image localized at the centre of the condyle in closed-mouth position alone. In our opinion, such assessment is imprecise and can give an incorrect impression of the attachment type. We noted earlier that the visibility of the LPM could be affected by different imaging projections, location of imaging layers and different jaw positions. Consequently, we investigated the muscle attachment in all oblique sagittal and coronal images, as well as in IP and OMP. This approach prevented mistakes in the assessment related to changes in muscle fibre configurations associated with the fibres' deflection by the articular tubercle in IP.

Our study showed a statistically significant correlation between the type of the LPM attachment and the presence of various disc positions. This finding stands in contrast to most of the studies investigating this relationship. Omami *et al*,⁷ Taskaya-Yilmaz *et al*,¹⁰ Imanimoghaddam *et al*⁶ and Dergin *et al*⁵ did not find

a statistically significant relationship between these variables. This discrepancy can partly be explained by the fact that our study group was larger and that we used a different methodology for disc assessment. TMJ disc position in these studies was analyzed in the sagittal plane alone, while in our study, it was analyzed in both the sagittal and coronal planes. In the study by Omami *et al*,⁷ pure anterior, anteromedial and anterolateral positions of the articular disc were regarded as anterior disc displacement. This could potentially explain the different outcome. Multidirectional TMJ disc displacements are equally as frequent as unidirectional ones.^{9,17} The method of assessment of TMJ disc position in the sagittal and coronal planes of MRI, presented by Larheim,⁹ Molinari *et al*²¹ and Ikeda *et al*,²⁰ and used in our study, seems to be most accurate in determining disc position in the TMJ. Consequently, a detailed analysis of both sagittal and coronal MR images is necessary to determine the position of the disc. The use of detailed classification of disc position was possible because of the large sample used in our study. This provided statistically significant results for each subgroup of disc position.

The LPM can be observed in MR images using various imaging projections, including the sagittal and coronal planes.^{23–25} Sagittal and oblique sagittal images of the TMJ are the most useful images for the diagnosis of internal derangement because these projections visualize the disc, condyle, fossa and sometimes the LPM on the same scan.^{24,26,27} However, there are no systematic reports on the visibility of the LPM insertion in different MRI projections on autopsy material.

In our study, the oblique sagittal and oblique coronal planes were used in order to compare the LPM insertion type with the TMJ disc position. The oblique sagittal plane is nearer to the parallel sections of the long axis of the LPM than the true sagittal plane. Therefore, it appears that oblique sagittal images of TMJ are most suitable for simultaneous evaluation of the LPM and disc position, provided all scans in this plane are analyzed.

We found a statistically significant association between the LPM attachment type and TMJ disc position in OMP MR images. In our study, Type I of muscle attachment, where the upper head of the LPM was attached only to the disc, positively correlated with disc displacement without reduction in the sagittal plane.

Table 4 The correlation between lateral pterygoid muscle (LPM) attachment type and temporomandibular joint (TMJ) disc position in open-mouth position in TMJ with disc displacement in intercuspal position in the sagittal plane

TMJ disc displacement	LPM attachment type							
	I		II		III		Total	
	n	%	n	%	n	%	n	%
With reduction	10	45.5	125	69.1	53	80.3	188	69.9
Without reduction	12	54.5 ^{a,b}	56	30.9 ^a	13	19.7 ^b	81	30.1
Total	22	100	181	100	66	100	269	100

$\chi^2 = 9.702$; $p < 0.01$; Pearson's contingency coefficient = 0.245.

^a $z = 2.21$; $p < 0.05$.

^b $z = 3.13$; $p < 0.01$.

Table 5 The correlation between the lateral pterygoid muscle (LPM) attachment type and temporomandibular joint (TMJ) disc position in open-mouth position in TMJ with disc displacement in intercuspal position in the coronal plane

	<i>LPM attachment type</i>							
	<i>I</i>		<i>II</i>		<i>III</i>		<i>Total</i>	
<i>TMJ disc displacement</i>	<i>n</i>	<i>%</i>	<i>n</i>	<i>%</i>	<i>n</i>	<i>%</i>	<i>n</i>	<i>%</i>
With reposition	2	40.0	40	47.6	19	48.7	61	47.7
Without reposition	3	60.0	44	52.4	20	51.3	67	52.3
Total	5	100	84	100	39	100	128	100

$\chi^2 = 0.135$; $p > 0.05$.

This finding corresponds to the results of Mazza *et al*,¹¹ who found that the presence of insertion of the LPM solely on the disc is associated with increased percentage of disc dislocation without reduction.

Our study design did not enable us to establish a cause–effect relationship between the LPM attachment type and the disc position. However, the results of experimental studies could support the theory on the causal relationship between these variables. Botulinum toxin injections to the LPM proved to be successful in treating disc displacement. The studies carried out by Emara *et al*²⁸ and Bakke *et al*²⁹ showed the disappearance of the click in all joints with anterior disc displacement after botulinum toxin injection into the LPM. These results were validated by pre- and post-operative MR images.

There is also another controversy concerning the role of the LPM in TMJ disc displacement. Hyperactivity of the muscle and poor coordination between the LPM heads are debated as aetiological factors of TMJ disc displacement.^{10,30} Different sites of insertion and sources of innervation may support this theory. Some anatomical studies reported that the upper head of the LPM enters only the capsule and disc and does not attach to the condyle.^{1,8,31} This was confirmed in our study also, as we found this type of insertion in 29 (7.6%) joints (Type I). Therefore, at least from the anatomical perspective, it is possible for the upper head of the LPM to pull the disc forward independently from the condyle,³² which may result in an anterior disc displacement. Moreover, this mechanism may also be possible in an attachment type where the upper head attaches to both the disc and condyle. Davies *et al*³² found that the superior head of the LPM has independent sources of innervation for the lower and upper segments of the muscle.

Nevertheless, muscle fibres are attached to not only the anterior but also the medial aspect of the disc–condyle complex.^{15,16} Therefore, it could be deduced that muscle fibres would tend to pull the disc in not only the anterior, but also the medial direction. In our study, there was some tendency for medial disc displacement in Type III attachment.

Even though the fibres of the superior head of the LPM are anteromedially oriented, Heylings *et al*¹⁵ do not believe that this would allow the disc to be displaced in an anterior and medial direction, since the muscle fibres are also attached to the condyle. Likewise, the data from our study showed a much higher incidence of normal disc

position in Type II, in which the upper head is attached to both the disc and condyle compared with Types I and III, in which the upper head is attached only to the disc. However, this difference was not statistically significant.

We found no statistically significant differences between the types of the LPM attachment in patients with normal, medial and lateral disc positions. However, there were differences in patients with disc displacement with an anterior component. Therefore, we hypothesize that the attachment type may be a cofactor in the perpetuation of disc displacement initiated by other factors (*e.g.* trauma). Wongwatana *et al*³¹ also suggest that the muscle attachment type does not play a significant role in disc displacement as long as the structure of the joint is normal. They reported that the upper head of the LPM contributed to the anteromedial displacement of the disc only in cases of prior damage to the disc, such as the stretching and/or tearing of its lateral or posterior attachment. In our study, such intra-articular changes as thinned discs and the elongation of retrodiscal tissues were observed in joints with disc displacement.

We also noted that muscle attachment type was associated with disc displacement without reduction in OMP in the sagittal plane. This makes us further hypothesize that attachment type of the LPM may be involved in the progression of disc displacement. Tanaka *et al*,³³ using a mathematical model, demonstrated that hyperactivity of the LPM during clenching may be involved in the progression of disc displacement.

The standard imaging protocol for visualization of disc position consists of oblique sagittal and oblique coronal images of the TMJ that are obtained perpendicular or parallel to the long axis of the mandibular condyle.³⁴ The diagnostic accuracy of MRI on fresh autopsy material using oblique sagittal and oblique coronal sections in determining the disc position has been found to be 95%.¹⁷

The results of our study showed that the LPM attachment types are correlated with the presence of certain types of disc displacement, predominantly those with an anterior component. In our opinion, the type of LPM attachment itself is unlikely to pose a risk factor for disc displacement. However, it is possible that certain types of the LPM attachment can contribute to the perpetuation and progression of disc displacement. Therefore, the attachment pattern of the LPM may be considered in the prognosis of this disorder.

It is important to elucidate the role of the LPM in the pathogenesis of the TMJ internal derangement, because the LPM may prove to be a target for potential therapies (*e.g.* botulinum toxin injections), which could improve the management of this disorder. Knowledge of the relationship between the LPM attachment types and disc displacement could be helpful in determining such therapies. We further propose that research based on clinical findings correlated with MR images of the TMJ and the LPM taken in the sagittal and coronal planes should be carried on in order to improve our knowledge on the pathomechanism of the TMJ derangement.

Conclusions

There is a significant correlation between certain types of LPM insertion and a disc position. Based on presented findings, we hypothesize that the type of LPM

attachment type may ease the perpetuation and/or progression of disc displacement with an anterior component. The present data suggest the need for further investigation to evaluate the role of LPM in the pathology of TMJ.

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