VIA MEDICA

ORIGINAL ARTICLE

Folia Morphol.
Vol. 71, No. 3, pp. 187–193

ISSN 0015–5659
www.fm.viamedica.pl

Clinical anatomy of the auriculotemporal nerve in the area of the infratemporal fossa

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[Received 17 May 2012; Accepted 2 July 2012]

The auriculotemporal nerve is a sensory branch extending from the posterior section of the mandibular nerve trunk. Its nerve roots form a short trunk, which gives off a number of branches, innervating: the temporomandibular joint, the temporal region, structures of the external ear: auricle, and external acoustic meatus, and the parotid gland. It also conducts excretory fibres to the buccal and labial glands. Anatomical relationships between the auriculotemporal nerve and the muscles of mastication, temporomandibular joint, and surrounding vessels in the area of the infratemporal fossa create favourable conditions for entrapment syndromes. Entrapment of the auriculotemporal nerve plays a role in the pathogenesis of temporomandibular joint pain syndromes, headaches, as well as pain symptoms or paraesthesias within the external acoustic meatus and auricle. The current study was performed on 16 specimens containing the infratemporal fossa. Some variations in the nerve roots of the auriculotemporal nerve were found and described as one-, two-, three-, four-, and five-root variants. The topography of the auriculotemporal nerve and its close relationship to the structures of the temporomandibular joint were described. Individually, the variable topography of the nerve course may play a role in the symptomatology of headaches and localisation of pain in the face regions and masticatory system. (Folia Morphol 2012; 71, 3: 187–193)

Key words: auriculotemporal nerve, auriculotemporal neuralgia, facial pain syndrome, auriculotemporal nerve entrapment

INTRODUCTION

Pain syndromes of the face are a serious diagnostic and therapeutic problem. Among the many different causes of pain symptoms are neuropathies arising as a result of masticatory system pathology [7, 10, 13, 17, 19, 23, 26, 27, 29, 34]. Symptoms usually occur as a result of compression of the nerve or nerve branch by neighbouring structures. The nerve may be pressed by normal anatomical structures or by pathologically changed ones, for example, hypertrophic lateral pterygoid muscle or dislocated structures of the temporomandibular joint (TMJ) [17, 23, 28]. Auriculotemporal nerve (ATN) entrapment is an important cause of pain syndromes of the face and masticatory system [9, 12, 22, 23, 28, 30, 31, 33, 34]. Symptoms of ATN entrapment include: pain or paraesthesias within the external acoustic meatus and auricle, a "feeling of obstruction" of external acoustic meatus, tinnitus, and pain radiating to the head of mandible and temporal area. Patients define this pain as "very intense and cutting". The symptoms may also occur in the form of facial tingling radiating to the upper jaw and to occipital region [14, 16, 29, 31, 33, 35]. Cases of ATN entrapment along with intense pain in the area of the upper molars have

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also been reported [24, 29]. While the mechanism of ATN entrapment has still not been clearly explained, the symptoms are related to the area of its innervation. ATN usually starts with two roots from the posterior margin of the mandibular nerve below its exit through the foramen ovale. Variations of one-, two-, three-, and four-roots of ATN have been described [3, 9, 31]. In the case of the two-root variation, the roots surround the middle meningeal artery (MMA), which goes toward the foramen spinosum. The roots of the nerve run between the lateral pterygoid muscle and posterior parts of tensor veli palatini. They fuse and form a short trunk, which extends laterally from the sphenoid spine and sphenomandibular ligament, and medially to the TMJ. The roots, ATN trunk, mandibular nerve, lingual nerve, inferior alveolar nerve, and maxillary artery are surrounded by a strong connective tissue sheath. Then the nerve trunk gives off numerous branches, which include: branches communicating with the facial nerve, articular branches, branches to the external acoustic meatus, anterior auricular nerve, superficial temporal branch, parotid branches, vascular branches, branches communicating with the otic ganglion and the mandibular nerve. Most descriptions are based on a two-root variant of ATN [1, 3–5, 8, 18, 20, 28, 30, 32, 36].

Due to the numerous disagreements about the mechanism of ATN entrapment relative to the small number of studies on the anatomy of this nerve, we decided to perform an anatomical study to evaluate the course and variability of ATN at the infratemporal fossa and to find potential correlations between the ATN course and the possibility of entrapment syndrome development.

MATERIAL AND METHODS

This study was carried out on 16 specimens with the infratemporal fossa fixed in 4% formaldehyde solution. The specimens were dissected using classical micro anatomical instruments and an operating microscope. Every step of dissection was documented. The dissected nerves: auriculotemporal, mandibular, lingual, and inferior alveolar, were described and measured.

The number of roots was determined by the order of their point of origin from the mandibular nerve trunk or the inferior alveolar nerve. The reference point was the foramen ovale. The thickness of the roots was measured at each point of origin from the mandibular nerve or inferior alveolar nerve. Length measurements were made in two ways: morphological and simplified length. Morphological length was measured from the point of root origin to the point of its connection with other roots. The simplified length was equal to the sum of the morphological length of the root and all the additional inter-radicular connections until the point of formation of the ATN trunk. The thickness of the ATN trunk was measured at the point of its origin formed by the combination of the roots. The length of the trunk was equal to the distance from the point of origin to the point of its first branch origin. The distance between the foramen ovale and the initial point of the ATN trunk was also measured (Fig. 1).

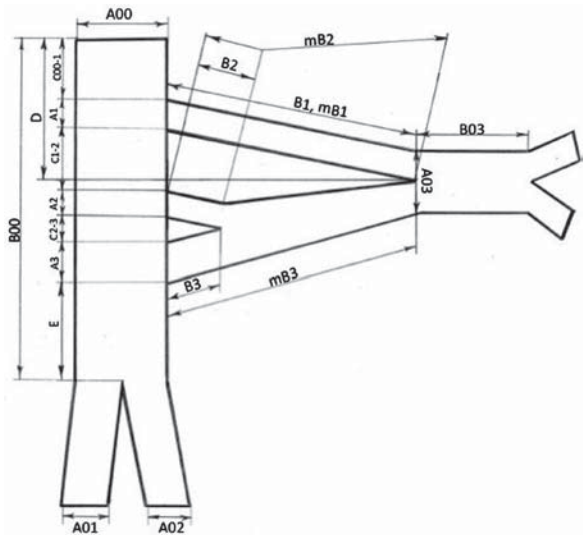

Figure 1. Schematic representation of auriculotemporal nerve (ATN) and its measurements; D — distance between the origin of the nerve trunk and the foramen ovale; E — the distance between the last ATN root and the mandibular nerve division; B0 — thickness of the mandibular nerve on the level of foramen ovale; B03 — the length of the ATN trunk; A03 — thickness of the nerve trunk in its initial part; COO-1 — the distance between the foramen ovale and the first ATN root; C1-2 — the distance between the first and second ATN roots; C2-3 — the distance between second and third ATN roots; A1, A2, A3 — the thickness of individual roots; B1, B2, B3 — the simplified length of individual roots; mB1, mB2, mB3 — the morphological length of individual roots.

The relationships of ATN to MMA and lateral pterygoid were also described. Results of the study were then analysed statistically using the Spearman statistical analysis method.

RESULTS

The number of ATN roots was from 1 to 5. The most frequent were the one- and two-root variants (5/16), followed by the five-root (4/16) and three-root variants (1/16). The four-root variant was observed in only one case (Fig. 2). In the five- and four-root variants, numerous complicated connections between particular roots were observed (Fig. 2). In five cases, the lower ATN roots started not from the mandibular nerve but from inferior alveolar nerve (Fig. 3). The average thickness of the first root was 2.67 mm, 1.7 mm

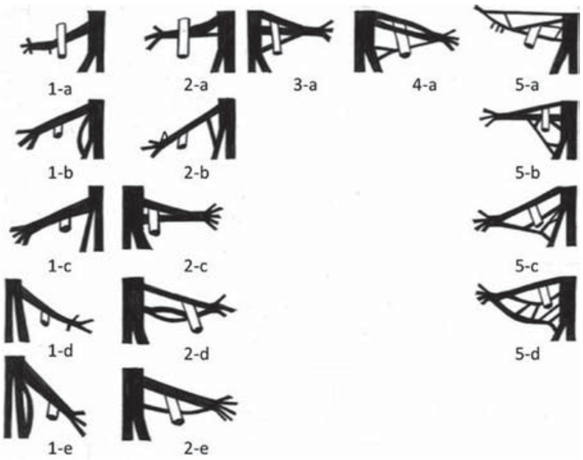

Figure 2. Variations and topographical relationships of auriculotemporal nerve and middle meningeal artery; 1-a, b, c, d, e — one-root variants; 2-a, b, c, d, e — two-root variants; 3-a — three-root variant; 4-a — four-root variant; 5-a, b, c, d — five-root variants.

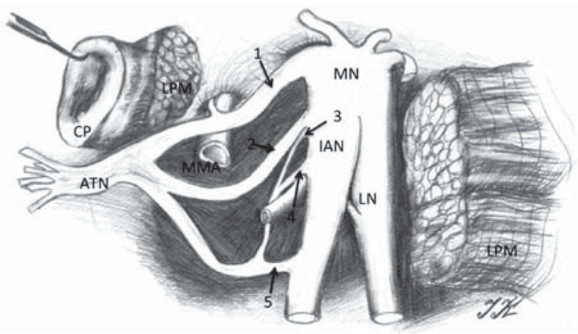

Figure 3. Variation of right auriculotemporal nerve with 5 roots. Lateral view. The ramus of mandible and middle part of lateral pterygoid was removed; CP — condyloid process; LPM — lateral pterygoid muscle; MN — mandibular nerve; IAN — inferior alveolar nerve; LN — lingual nerve; ATN — auriculotemporal nerve (trunk); MMA — middle meningeal artery; 1, 2, 3, 4, 5 — particular roots of ATN.

for the second root, 1.14 mm for the third root, 1.19 mm for the fourth root, and 0.98 mm for the fifth root. Typically, the first roots were the thickest and the fifth roots were the thinnest. The average simplified length of roots was, respectively, as follows: 14.76 mm for the first root, 11.95 mm for the second root, 12.22 mm for the third root, 18.35 mm for the fourth root, and 19.83 mm for the fifth root. The average morphological root lengths were: 14.41 mm for the first root, 7.95 mm for the second root, 7.74 mm for the third root, 4.58 mm for the fourth root, and 3.54 mm for the fifth root. Average ATN trunk thickness ranged from 2.02 mm to 5.62 (mean 3.18 ± 0.84) mm. The average ATN trunk length ranged from 0 to 20.7 (mean 6.32 ± 5.91) mm (Table 1).

Table 1. Measurements of auriculotemporal nerve (ATN)

	Min.	Max.	Mean ± SD
D	3.77	20.47	11.52 ± 4.33
E	–21.90	7.94	–2.97 ± 8.27
B00	3.57	24.16	12.06 ± 5.56
B03	0.00	20.70	6.32 ± 5.91
A03	2.02	5.62	3.18 ± 0.84
C00-1	0.00	5.12	2.47 ± 1.87
C1-2	0.00	6.28	2.59 ± 2.45
C2-3	0.00	8.55	1.87 ± 2.74
C3-4	0.00	7.41	2.56 ± 3.03
C4-5	0.00	7.00	3.53 ± 3.14
A1	1.30	8.08	2.67 ± 1.65
A2	0.55	3.46	1.70 ± 1.02
A3	0.52	2.06	1.14 ± 0.57
A4	0.70	1.81	1.19 ± 0.51
A5	0.54	1.72	0.98 ± 0.56
B1	1.40	38.00	14.76 ± 8.11
B2	2.45	32.00	11.95 ± 7.75
B3	6.55	24.50	12.22 ± 6.53
B4	3.55	50.16	18.35 ± 18.28
B5	10.80	37.99	19.83 ± 12.29
mB1	1.40	38.00	14.41 ± 8.34
mB2	1.00	28.00	7.95 ± 7.84
mB3	2.00	20.50	7.74 ± 6.98
mB4	1.07	16.67	4.58 ± 6.78
mB5	1.50	6.05	3.54 ± 1.96

D — distance between the origin of the nerve trunk and the foramen ovale; E — distance between the last ATN root and the mandibular nerve division; B00 — length of the mandibular nerve from the foramen ovale to the point of division on inferior alveolar nerve and lingual nerve; B03 — length of the ATN trunk; A03 — thickness of the ATN trunk in its initial part; C00-1 — distance between the foramen ovale and the first ATN root; C1-2 — distance between the first and second ATN roots; C2-3 — distance between second and third ATN roots; C3-4 — distance between third and fourth ATN roots; C4-5 — distance between fourth and fifth ATN roots; A1, A2, A3, A4, A5 — thicknesses of individual roots; B1, B2, B3, B4, B5 — simplified lengths of individual roots; mB1, mB2, mB3, mB4, mB5 — morphological lengths of individual roots

The course of the MMA was variable. Most frequently, the artery went between the first and second root of the ATN (in 7 cases out of 16) (Table 2).

In one case an anatomical variant was seen in which the nerve pierced the lateral pterygoid muscle (Fig. 4). In this five-root variation long roots penetrated the lateral pterygoid in its upper and medial parts. Then nerve roots emerged from the lower edge near the insertion of the muscle to fuse in the short

Table 2. Relationships between the auriculotemporal nerve and the middle meningeal artery

Variation	Location of middle meningeal artery					
	Laterally	Medially	1–2	2–3	3–4	4–5
1 root	1	4				
2 roots	1	1	3			
3 roots			1			
4 roots				1		
5 roots			3		1	

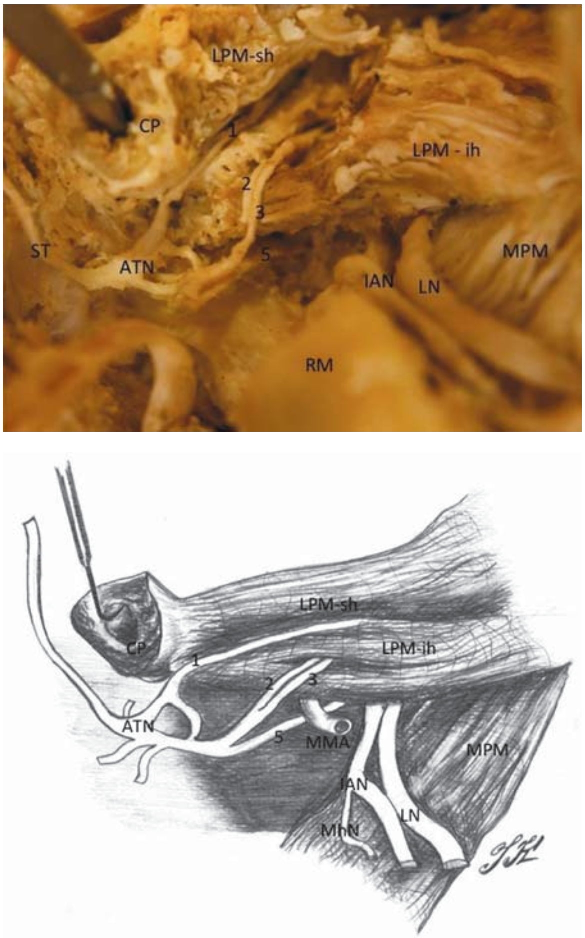

Figure 4. Five-root variant of the right auriculotemporal nerve. The roots run through the lateral pterygoid muscle. The first root passes between the heads of the lateral pterygoid, the second and third through the inferior head of the lateral pterygoid muscle. The fourth is very short, hidden behind the muscle and, just from its point of origin from the mandibular nerve, is connected with the fifth root. The fifth root goes under the inferior head of muscle; CP — condyloid process; RM — ramus of mandible; LPM-sh — lateral pterygoid muscle (superior head); LPM-ih — lateral pterygoid muscle (inferior head); MPM — medial pterygoid muscle; MhN — mylo-hyoid nerve; IAN — inferior alveolar nerve; LN — lingual nerve; ATN — auriculotemporal nerve (trunk); ST — superficial temporal branch of ATN; MMA — middle meningeal artery; 1, 2, 3, 5 — specific roots of ATN (the fourth root is covered by the muscle).

trunk on the medial surface of the TMJ capsule. The upper or first root passed between the heads of the lateral pterygoid muscle, the second and third roots passed through the inferior head of lateral pterygoid, and the fourth root was very short and — just from the point of origin from the mandibular nerve trunk — was connected to the fifth root, which ran under the lower head of the muscle (Fig. 4).

DISCUSSION

Our knowledge of ATN anatomy is based on different anatomical textbooks and atlases [1, 5, 6, 8, 18, 32, 36, 37]. In the literature the ATN is usually discussed in chapters about trigeminal nerve branches and infratemporal fossa anatomy. However, these sources always replicate the fixed bifurcated pattern of ANT that is pierced by the MMA. Meanwhile, some authors have pointed out the high variability of this nerve [3, 9]. On the basis of previous research results, the number of ATN roots is highly variable.

In some studies, one can find a description of nerve variants having from one to four roots [3]. Generally the one- and two-root variants are mentioned as the most common variants, but there are some discrepancies in these research results. Baumel et al. [3] consider the two-root variant as the most common (62/85 cases). In our own research, we only found a small number of other variants: three-root (12/85), one-root (10/85), and four-root (1/85).

On the other hand, Gülekon et al. [9] observed that the one-root variant is the most common (16/ /32 cases), relative to two-root (12/32), three-root (3/32), and four-root variants (1/32). In one study a two-root variation is described in which the lower root is divided into three smaller roots [31]. Despite so many articles describing the high variability of the ATN in the infratemporal part, many studies limit themselves to describing the nerve in its segment located outside the infratemporal fossa [3, 12, 14, 28]. Most papers, which are the main source of anatomical knowledge about the ATN, list only the two-root variant [1, 5, 6, 8, 15, 18, 32, 36, 37].

There is no clear criterion for determining the precise architecture of ATN roots. The structures that one group classify as the nerve roots [9], others classify as connecting branches [15]. In our study, all the structures that originated from the mandibular nerve or inferior alveolar nerve and directly or indirectly participated in the formation of the ATN trunk were considered as nerve roots. In two cases of one-root variations, there was an additional branch that ran vertically from the mandibular nerve to the infe-

Figure 5. The dissected auriculotemporal nerve (ATN) exposed of photographs; **A.** One-root variant of ATN, left side; **B.** Two-root variant of ATN, left side; **C.** Three-root variant of ATN, left side; **D.** Four-root variant of ATN, left side; **E.** Five-root variant of ATN, right side; MN — mandibular nerve; IAN — inferior alveolar nerve; LN — lingual nerve; auriculotemporal nerve (trunk); 1, 2, 3, 4, 5 — particular roots of ATN.

rior alveolar nerve (Figs. 2, 5), which can be treated as one root of a divided mandibular nerve trunk. Similar variations have been reported before [2].

Some authors point out that ATN roots do not always have their origin from the mandibular nerve but branch off much lower — from the inferior alveolar nerve [3, 9]. We observed such a situation in three cases of five-root variant and in one case each of four-root and two-root variants — in 5/16 cases in total (Fig. 2). It can be concluded that multi-root variations predispose to nerve roots exiting very low from the trunk. Such low exits of the ATN nerve roots are likely to be the cause of atypical symptoms of anaesthesia of the external ear during inferior alveolar nerve anaesthesia in dental procedures [25].

According to Gülekon et al. [9], the thickness of the ATN roots varies from 0.65 mm to 2.54 mm for the first root, from 1.96 mm to 0.49 mm for the second root, from 0.66 mm to 1.17 mm for the third root, and is equal to 0.67 mm for the one case of four-root variant. These results are similar to our data (Table 1).

The length of the nerve roots is also similar to results obtained by other authors. Typically these are 18.5 mm for the first root, 18.7 mm for the second, 17.48 mm for the third, and 29.66 mm for the fourth [9]. According to Baumel et al. [3], the average length of all roots is equal to 15 mm, and individual lengths vary from 5 to 23 mm. However, these authors do not specify exactly how the measurements of roots were taken. It can be assumed that they were measured from the point of origin on the mandibular nerve trunk or the inferior alveolar nerve trunk to the point of origin of the ATN: a value that in our measurements was called the "simplified length". The morphological length of the root changes according to the number of roots, being highest for the first root and successively smaller for each of the next.

The average length of the nerve trunk according to the literature is 6 mm [3]. It is comparable to our results.

Furthermore, in our analysis, a statistically significant positive correlation between total root thickness and the number of roots ($r = 0.62$, $p < 0.01$) (Fig. 6) was found. This means that the greater the number of roots in a particular variation, the greater the sum of the thicknesses. So, if we compare a one-root variation with a multi-root variation of the nerve, the sum of the thicknesses of their roots will not be equal but will increase with the number of roots. This is logical and can be explained by the presence of the nerve sheath. The value of the mea-

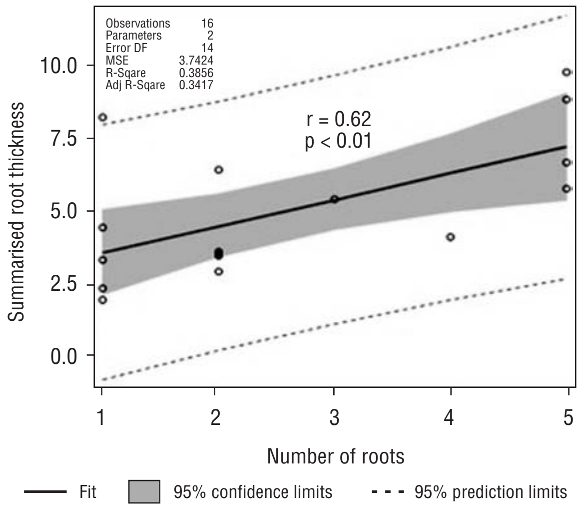

Figure 6. Correlation of summarised root thickness and number of auriculotemporal nerve roots.

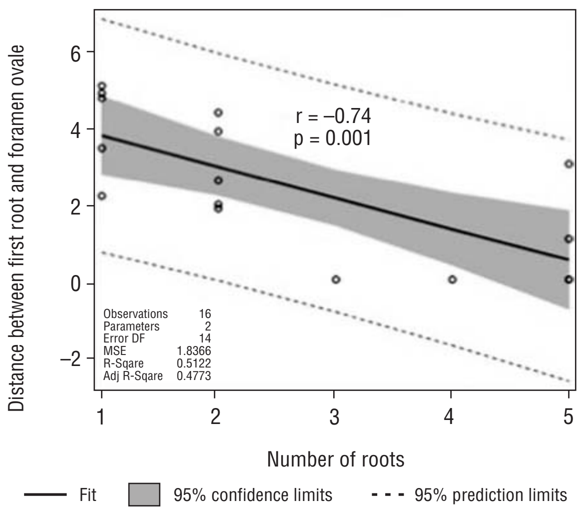

Figure 7. Correlation of distance between first root and foramen ovale and number of auriculotemporal nerve roots.

surements is a sum of the value of nerve fibre bundle thickness; in particular, the root and nerve sheath double thickness for each of the roots. Therefore, in the observed multi-root variation the total thickness of the roots increases. We also observed a statistically significant negative correlation between the number of roots and the distance from the point of origin of the first root to the foramen ovale ($r = –0.74$, $p < 0.001$) (Fig. 7). Already at the stage of preparation, it was observed that a high point of origin of the first nerve root is often associated with the presence of more nerve roots in the nerve. This was confirmed by the results of statistical analysis. In conclusion, it appears that the smaller the distance between the foramen ovale and the point of origin of the first nerve root, the greater the number of its roots. And vice versa: the greater the number of roots, the higher the first root is located. In addition, a few more correlations were found: a positive correlation between the length of the nerve trunk and the number of roots ($r = 0.49$, $p < 0.056$) and a negative correlation between the distance from the foramen ovale to the ATN trunk and the number of its roots ($r = –0.73$, $p < 0.001$).

Comparing the relationship of the ATN to the MMA, our results are very similar to results obtained by other authors in previous studies. According to Gülekon et al. [9], in the one-root variation, the artery ran laterally to the nerve in 8/16 cases, medially in 7/16 cases, while in one case the authors did not identify the location of the vessel. In the two-root variation the vessel proceeded laterally in 2/12 cases, and between the first and second root in 10/12 cases. In the three-root variation (1/3 of cases), the artery ran medially in one third of the cases and between the first and second root in the remaining two-thirds. In the four-root variation, the artery typically ran between the first and second root. Other authors observed similar nerve architecture. In two-root variations, they described the artery between the first and second root in 52/62 cases, medially to the nerve in 6/62 cases, and laterally to the nerve in 4/62 cases. In one-root variations, the artery was located laterally to the nerve in 8/10 cases and medially in 2/10 cases. In three-root variants, the artery was seen to be placed between the first and second roots in 6/12 cases, and between the second and third roots in the other 6/10 cases [3]. In our study, in all variants in which the MMA was surrounded by the roots of ATN, the roots lying on the artery were located lateral to it. This position was observed in all such cases (Fig. 2, Table 2). However, in one study, the authors found a two-root variation in which the upper root was placed medially to the artery, while the lower one was placed laterally. The relative topography of the ATN and MMA is important during any sub-temporal approach to the middle cranial fossa or infratemporal fossa. In such cases the MMA is a reference structure to the ATN. Frequently MMA have to be dissected free, coagulated, and divided without ATN injury.

Topographical relations in the area of infratemporal fossa promote ATN entrapment. Nearly all the space of the infratemporal fossa is filled by the muscles belonging to the functional group of mastication, as well as with important blood vessels and nerves [1, 5, 8, 21].

Overloading and hypertrophy of masticatory muscles can occur as a result of dysfunction within the stomatognathic system [7]. Hypertrophic masticatory muscles, especially the lateral pterygoid, reduce the free space at the infratemporal fossa, creating favourable conditions for the compression of the ATN. Previous studies have described an anatomical variation in which mandibular nerve branches pass through the lateral pterygoid muscle [7, 11, 22, 30]. Penetration of the lateral pterygoid muscle by ATN is quite rare [22, 30]. This kind of variation appeared only in one case in our study.

It is also worth noting that in all cases, the ATN lying at the TMJ level (at this level the roots are typically already united in the trunk) ran directly adjacent to the medial surface joint capsule. Similar results were observed by other authors [28].

Such topographical relationships probably play a role in nerve entrapment. Dislocations of the TMJ structures, caused by inflammation or injury, may exert pressure on the nerve, producing symptoms of entrapment [19, 23, 26]. Based on previous data, we can point to two main factors that determine the presence of ATN entrapment in its course within the infratemporal fossa. The first is anatomical variation, while the second is the presence of various types of dysfunction within the masticatory system that initiates a series of morphological changes and ultimately leads to entrapment. In such situations, even small functional or structural changes within the stomatognathic system can lead to pain syndromes.

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