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Review

Anatomical and clinical significance of Pterygospinous and Pterygoalar ligaments and bony bars in dentistry.

Significado anatómico y clínico de los ligamentos Pterigoespinoso y Pterigoalar y los puentes óseos en odontología.

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Abstract: The Pterygospinous Ligament (PSL) extends from the Pterygospinous process of the lateral Pterygoid plate to the spine of the sphenoid bone. Sometimes, it may be ossified forming a bar of bone bounding the pterygospinous foramen to which mandibular nerve and its branches are variably related. Mandibular and chorda tympani nerves may get compressed depicting various clinical symptoms, which in turn depend upon dimensions of the foramen and grades of compression. Therefore, knowledge of the position and extent of ossification of PSL and its relation to the important structures in the deep infratemporal fossa is important for radiologists, neurologists, maxillofacial surgeons, dental surgeons and anesthesiologists during various anesthetic and surgical procedures.

Keywords: Pterygoid; ligaments; foramen ovale; sphenoid bone; oral and maxillofacial surgeons.

Resumen: El ligamento Pterigoespinoso (LP) se extiende desde el proceso Pterigoespinoso de la placa Pterigoideo lateral a la espina etmoidal del hueso esfenoides. A veces, se puede osificar formando un puente de hueso que une el foramen espinoso con el cual el nervio mandibular y sus ramas están relacionados de manera variable. Los nervios mandibulares y el cordón timpánico se pueden comprimir resultando en diversos síntomas clínicos, que a su vez dependen de las dimensiones del foramen y los grados de compresión. Por lo tanto, el conocimiento de la posición y el grado de osificación del ligamento pterigoespinoso y su relación con las estructuras importantes en la fosa infratemporal profunda es importante para radiólogos, neurólogos, cirujanos maxilofaciales, cirujanos dentales y anestesistas durante diversos procedimientos anestésicos y quirúrgicos.

Palabras Clave: *Pterigoideo; igamentos; foramen oval; hueso esfenoides; cirujanos.*

INTRODUCTION.

The ligaments are tough, flexible fibrous bands that connect the adjacent bones and hold them together, or they may be membranous folds that support organs. Fibrous ligaments function as binding bands between the structures they connect. There are several such ligaments at the base of the skull, in relation to the sphenoid bone, such as the interclinoid, caroticoclinoid, pterygospinous (PSL) and pterygoalar ligaments (PAL). The ossification of the fibrous ligaments may lead to many clinical symptoms related to the compression of delicate structures, especially nerves.[1] Normal surgical pathways can be obstructed by the ossification of ligaments at the cranial base which can also interfere with common operative procedure. The fibrous

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structures in various parts of the body may become secondarily ossified leading to the formation of osseous bridging. It is a frequent, poorly understood, age dependent process.[2] When these bony bridges present in children it indicates the possible role of hereditary factors.[3] The PSL and PALs are located near the foramen ovale and they maintain an important clinical relationship with the nearby structures. These ligaments can become ossified leading to symptomatic compression, especially of vessels and nerves passing through the foramen ovale, resulting in compressive syndromes. However when the ossified PSL (pterygospinous bar) presents medial to the foramen ovale, it may not have much clinical significance.[4]

MATERIALS AND METHODS.

A thorough search was done in databases like Scopus and Pubmed using the keywords PSL, pterygoalar ligament, Foramen of Civinini, Foramen ovale, Mandibular nerve, Lateral pterygoid muscle. please delete lateral pterygoid ligament and Infratemporal fossa. The articles were collected from 1931 to 2017.

Attachments, extent and ossification of Pterygospinous and Pterygoalar ligaments.

The lateral pterygoid plate, which is located at the base of the human skull, presents a small backward projection called the pterygospinous process or spine of Civinini in the upper part of its posterior border. The PSL is a fibrous ligament that connects the pterygospinous process of the lateral pterygoid plate to the spine of the sphenoid bone. From an evolutionary perspective, when the pterygoid bone was separate from the basisphenoid bone it had a vestigial function. (Figure 1 and Figure 2)

The ligament lies inferior or deep to the foramen ovale. Sometimes there may be another spur near the lower end of the posterior border of the lateral pterygoid plate for the attachment of a second PSL, thus two ligaments, a long and a short ligament may be present. The thickening of the upper part of fascia between the lateral and medial pterygoid muscles forms the PSL.

It is occasionally replaced by pterygospinous muscle that is inserted into the temporomandibular joint capsule extending to its articular disc.[5]

Frazer observed the PSL extending from a more or less prominent projection of the lateral pterygoid plate, from its posterior edge to the base of the sphenoidal spine. He also reported that the anterior attachment of the ligament to the posterior border of lateral pterygoid plate is variable and that both a long and short ligament may be present.[6] Ossification may extend someway into these ligaments, leading to the formation of a bony bar in place of the ligament.

The nerves issuing from the foramen ovale have varying relations to these ligaments.[6] Hyrtl described the PAL near the anterolateral edge of the foramen spinosum (Hyrtl's ligament), which extends from the root of the lateral pterygoid plate to the infratemporal surface of the greater wing of the sphenoid.[7] The PSL lies below or medial to the foramen ovale whereas the PAL is situated lateral or below the foramen which divides it into two parts.

These ligaments may ossify or calcify either completely or incompletely forming the respective bony bars.[1] Ossification is complete if the bony bridge extends from the lateral pterygoid plate to the apex of the spine of sphenoid, and it is considered incomplete if the pterygospinous bony bar (PSB) fails to attach to spine of sphenoid.

Between the upper border of the PSB and the base of the skull, a foramen called pterygospinous foramen (of Civinini) is formed. This foramen is completed by the cribriform fascia, which is an upward continuation of the interpterygoid fascia or aponeurosis that is bisected by the accessory meningeal artery, the medial nerve pterygoid and the tensor veli palatini muscle.

The ligament lies below or medial to the foramen ovale. Sometimes the ligament may be transected by the pterygoid venous plexus. The neurovascular structures may be entrapped by the ossification of the ligament and cause mandibular nerve block.

Rouviére *et al.*,[8] have reported that the sphenomandibular ligament is divided by the PSL into two independent structures, of which the interpterygoid fascia is thin. There is another fibrous plate lateral to the interpterygoid fascia that is attached to the greater wing of the sphenoid and into the upper part of the posterior border of the lateral plate in the pterygoid process. Its upper edge becomes flat and forms an un-named

ligament that posteriorly it is known as the PAL.[9] When this ligament becomes ossified, it forms the lower boundary of the pterygoalar foramen. (poruscrotaphitico-buccinatorius)

Extent of ossification of these ligaments

Ossification of these ligaments may be complete or incomplete. Ossification is complete, if the bony bridge extends from the lateral pterygoid plate to the sphenoidal spine apex, and is considered as incomplete if the PSB fails to get attached to the spine of sphenoid. (Figure 3 and Figure 4)

When a complete pterygospinous bony bar is formed, a well-defined pterygospinous foramen is present while, in case of partial ossification an incomplete bony bar results and a partial foramen bounded by this incomplete bar is formed.

Figure 1. Lateral view of the skull showing the pterygospinous process (PtS P) projecting backwards from the lateral pterygoid plate (LPP). The spine of the sphenoid bone (SS) can also be observed.

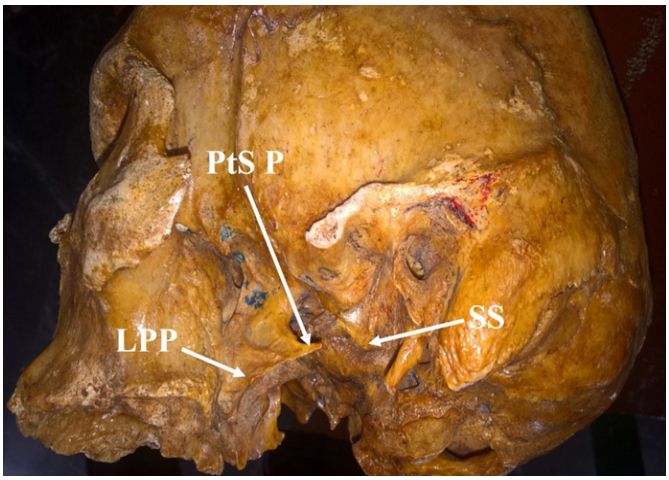

Figure 2. Inferior view (norma basalis) of the skull showing two pterygospinous processes on each side. Bilateral inferior (PtS P-1) and superior (PtS P-2) pterygospinous processes are seen projecting backwards from the lateral pterygoid plate.

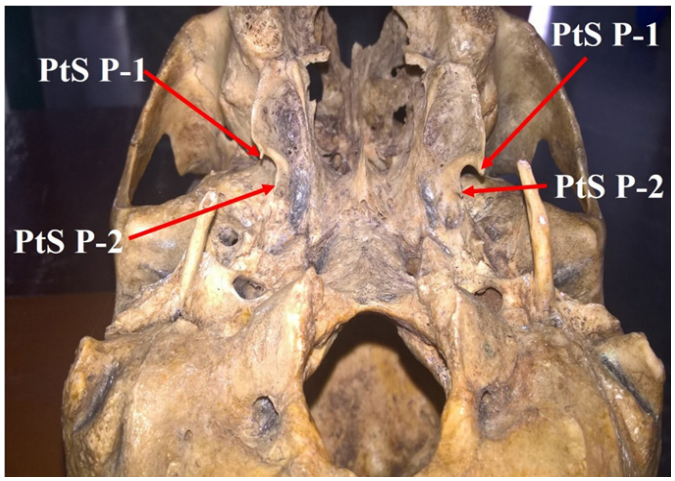

Figure 3. Inferior view (norma basalis) of the skull showing two pterygospinous processes (PtS P-1 and PtS P-2) on right side projecting backwards from the lateral pterygoid plate each side. However, on left side the pterygospinous bar can be seen connecting the lateral pterygoid plate (LPP) with the spine of the sphenoid bone (SS).

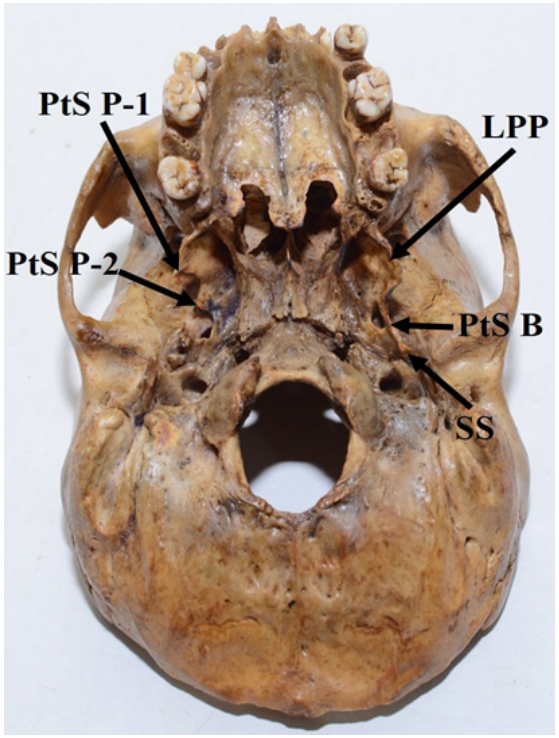

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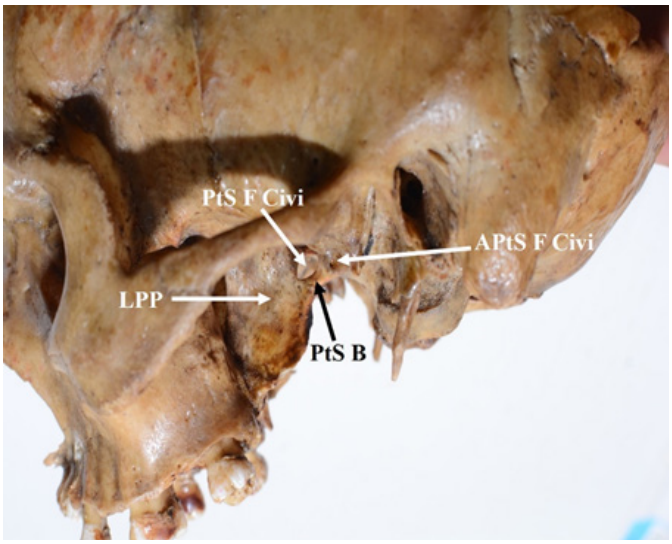
Figure 4. Lateral view of the skull showing the pterygospinous bony bar (PtS B) projecting backwards from the lateral pterygoid plate (LPP). The pterygospinous foramen of Civinini (PtS F Civi) and an accessory foramen of Civinini (APtS F Civi) can be also observed.



DISCUSSION.

As far as pterygospinous bony bar measurements are concerned, in case of complete pterygospinous bridging, the length of the PSB ranged from a minimum of 5 mm to a maximum of 10.5 mm while the width of the PSB ranged from 1.5 mm to 3 mm; the maximum diameter of the pterygospinous foramen ranged from 5 mm to 10.5 mm. In case of incomplete bridging, the gap or distance between the two non-meeting ends ranged from 3 mm to 7 mm.[10] A wide range of variation based on the topography, geography and race have been reported by different researchers.

Von Ludinghausen *et al.,*[11] observed completely ossified PSL in 1.85% of cadavers and 6% of dry human skulls. Wood Jones[12] reported 8% ossified PSL in Hawaiian skulls whereas Peker *et al.,*[13] reported that 8.8% of skulls of Anatolians showed the presence of this bony bar. Nayak *et al.,*[14] noticed the presence of a pterygospinous bony bar in 9.61% of Indian dried skulls, out of these 5.76% were complete and 3.84% were incomplete.Suazo *et al.,*[15] reported an incidence of only 1.6% of completely ossified PSBs in a sample of 312 skulls.

A radiographical study of 93 dried skulls showed PSL in 27.97% of radiographs, out of which 19.36% were partially ossified and 8.61% were completely ossified.[16] Only 1.31% of complete PSBs were observed by Kapur *et al.,*[17] in a study of 305 Croatian skulls.

However a study conducted by Goyal *et al.,*[4] showed not even a single total complete PSB out of 55 cases. Antonopoulou *et al.,*[9] reported incomplete ossification of PSLs in 25 out of 50 skulls and bilateral complete pterygospinous bony bars in one. Das *et al.,*[18] noticed ossified PSB on the right side of only one skull out of 100 skulls. Tubbs *et al.,*[19] reported an incidence of ossification of both pterygospinous and PALs in dried skulls. They stated that such bony anomalies could be an obstacle while placing a transcutaneous needle into the foramen ovale. Peker *et al.,*[13] have reported complete ossification of PSL in 5.5% of skulls and complete bilateral ossified pterygospinous bridges in 3.1% of skulls.

However, Ghai *et al.,*[20] observed complete bilateral ossified PSBs in only one out of 50 skulls. von Ludinghansen *et al.,*[11] in their study on 100 Japanese skulls and 54 German cadavers noticed completely ossified PSL in 6% of skulls and 1.85% of cadavers, PSL in 20.4% of cases, pterygospinous muscle in 9.2% of cases. This muscle, which is considered a third head of the lateral pterygoid, is attached to the capsule and articular disc of the temporomandibular joint.

Peker *et al.,*[13] found in their study of Anatolian skulls, completely ossified PSL in 5.5% of skulls, completely ossified PAL in 4.9% cases; complete bilateral ossifi-

cation of PSL in 3.1% of skulls, completely ossified bilateral PAL in 2.9%, the frequency of completely ossified PSL bar was 4.2% on the right and 6.4 % on the left. Furthermore, frequency os pterygoalar bars was 4.2% on the right and 5.5 % on the left. They found a PAL in a white adult male on the left only. Of the 416 Indian skulls studied by Nayak *et al.,*[14] 9.61% had PSL bony bridge of which 5.76% were complete and 3.84% incomplete. Suazo *et al.,*[15] reported 1.6% completely ossified PSL out of 312 skulls. Studies by Das *et al.,*[18] and Tubbs *et al.,*[19] have reported only one ossified ligament.

Tubbs *et al.,*[19] observed two ossified pterygospinous and PALs in a sample of 154 adult human skulls.[20] Krmpotić-Nemanić *et al.,*[21] reported five ossified PSLs out of 100 skulls. Pinar *et al.,*[22] found 12 completely ossified PSLs, 4 completely ossified PALs and 35 incompletely ossified PSLs, and 18 incompletely ossified PAL out of 361 skulls.22

Kapur *et al.,*[17] reported the presence of 18.36% of PSBs among 305 Croatian skulls. Out of incompletely ossified PSL, one was on the right and another on the left. Agarwal *et al.,*[23] found 9.7% of PSBs out of 67 skulls of the Punjab region, of which, 2.99% were completely ossified and 6.72% were incompletely ossified. Verma *et al.,*[24] reported a total incidence of 18% of PSL ossification among 116 dried skulls.

Kamath *et al.,*[25] reported an incidence of 17% of PSB and 30% of pterygoalar bar in their study. They also mentioned that pterygospinous and pterygoalar bars were positioned mostly inferior to the foramen ovale but, and in a few cases they were medial to the foramen.

Tubbs *et al.,*[19] Reported only one foramen with completely ossified PSB was seen among 154 adult human skulls. In another study, 10% of 454 skulls of different races, presented pterygospinous foramen,[26] while 5.46% of 2745 skulls of Americans of various ethnicities showed pterygospinous foramen to be more frequent in Whites.[27]

Suazo *et al.,*[28] reported the maximum diameter of the foramen of Civinini as being 10.62 mm from their study on 312 Brazilian skulls. Occurrence of PSB from populations of Europe, the North Pacific coast and Japan was 4.5%, 5.9% and 4% respectively.[29,30] The area of the foramen of Civinini has been reported from 16.72 to 94.2 square mm.[31,32] The reported width of the PSB ranges from 3.5mm to 4.5mm and the length varied from 11mm to 12mm.[7,14,32] The gap between the sphenoidal spine and spine of Civinini was found to vary from 0.3mm to 3mm.[33,34]

One large foramen of Civinini and also an accessary foramen of Civinini were found unilaterally among 160 assessed cases.[32] Radiographically, ossification of PSL can be observed by Hirtz axial or submentovertex technique and also by Panorax and transmaxillary views.[2,16] The para- and retromaxillary spaces may be superimposed by a complete pterygospinous bony bar or a foramen of Civinini in a radiographic picture. In a radiographically guided trigeminal ganglion blockage the PSL can be an obstacle.[9,26,35]

Clinical significance of the pterygospinous ligament, bar and pterygospinous foramen

The foramen of Civinini transmits branches of the mandibular nerve to masticatory muscles such the temporalis, masseter and lateral pterygoid muscles.[1] A pterygospinous bony bar may interfere with mandibular nerve block for pain relief in mandibular fractures or in cancer patients.[24,26] Blockage of foramen ovale due to the ossification of the ligaments may cause difficulties in the assessment of foramen ovale.[36]

The lingual branch of the mandibular nerve is usually protected against compression entrapment and tension by the soft tissues of tensor veli palatini and lateral pterygoid muscles between which it courses down.[37] Presence of a pterygospinous bony bar can lead to the entrapment of the lingual nerve between this bony bar and the pterygoid muscles during their contraction, leading to numbness in the respective area of innervation, as well as loss of taste on the anterior two thirds of the tongue and pain during talking.[35]

A pterygospinous bony bar or a wide lateral pterygoid lamina can cause mandibular neuralgia and the bony bar itself can be an obstacle for a mandibular block.[17] Increased width and flattening of the lateral pterygoid plate poses difficulties during surgery of the pterygoid region due to lack of space.[16] Compression of the lingual nerve by a completely ossified PSL and medial pterygoid muscle was reported by Peuker *et al.*[1]

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An ossified PSL can compress deep infratemporal structures like the mandibular nerve and its branches, otic ganglion, middle meningeal vessels, chorda tympani nerve and pterygoid muscles resulting in symptoms. An ossified PAL could be an obstacle while placing a transcutaneous needle into oval foramen.[19] Presence of these bony bars reduces accessibility into para and retropharyngeal spaces, resulting in difficulties in accessing the foramen ovale during therapeutic approaches to the base of the skull. A pterygospinous bony bar can be a hindrance to mandibular anesthesia by lateral subzygomatic route.[38] The bar covers the oval foramen and obstructs the needle penetration through the foramen ovale during a percutaneous procedure for the treatment of trigeminal neuralgia.[39] Thermocoagulation of trigeminal ganglion is also difficult in the presence of these ligaments.[32] Visualization of the foramen ovale and related structures radiologically can make puncture easier and more precise.[40] Anatomical knowledge of these bony bars is beneficial for anesthetics, dental and maxillofacial surgeons during the treatment of neuralgia.[20]

Furthermore, the foramen ovale may be obliterated by these ligaments resulting in mandibular neuralgia.[41] In those patients where other causes of compressive syndrome cannot be diagnosed, compression of the regional structures like nerves by these bony bars should be considered.[42] They can obstruct the surgical route and interfere with the operative access.

A pterygoalar foramen formed by an ossified PAL transmits masseteric and deep temporal nerves which are susceptible to compression by the ossified bar of bone, producing neurological disturbances.[43] Peukar *et al.,*[1] described a case of lingual nerve entrapment between the PSB and the medial pterygoid muscle leading to pain and speech alterations. Newton *et al.,*[35] reported an obstacle caused by an ossified PSL in a radiographically guided trigeminal ganglion blockage. Knowledge of these bony bars and ligaments is important for surgeons, anesthetists, radiologists, and neurologists in order to increase the success rate of surgical procedures and to cure pain from compression.[25]

The mandibular nerve distribution pattern may be affected by PSBs and ligaments.[44] The mandibular nerve trunk can be redirected laterally by the presence of these bony bars.[2] The lingual nerve may be divided into anterior and posterior parts by the pterygospinous bony bar which pierces the nerve.[36]

The anterior part is susceptible to compression because it lies between the tensor veli palatini muscle and the bony bridges, leading to sensory loss on the anterior two thirds of tongue, lingual gum anesthesia, articulation related pain and signs of vascular compression of the trigeminal ganglion. Entrapment of motor mandibular nerve branches can lead to paresis or weakness of the supplied muscles.

PAL and bony bar may also possibly compress the deep temporal, buccal, auriculotemporal, chorda tympani or lingual nerves, and nerves to the lateral pterygoid causing chewing disorders, pain and numbness in the buccal region, sensory changes in tongue and parotid gland secretion changes.

Cranial base CT scan, Hirtz axial radiograph and submentovertex projection provide the position of obstructive/compressive structures related to foramen ovale, which when present, an inframandibular approach is recommended instead of normal supramandibular or transzygomatic approach to overcome the failure of a trigeminal ganglion block.[16,45]

Topographical knowledge of the bony bars at the base of the skull around the oval foramen may be very helpful for diagnostic and neurological procedures like percutaneous biopsy of cavernous sinus tumors, electroencephalographic analysis and microvascular decompression by percutaneous trigeminal rhizotomy.[46] An important bony landmark in conducting mandibular anesthesia is the lateral pterygoid plate but the ossified bony bars pose an obstacle to the procedure. Knowledge of the osseous bars at the cranial base and their radiological evaluation enables the surgeons to understand and treat complex clinical neuralgias of the oral and maxillofacial regions and enables proper planning for the surgical procedures. Branches of the mandibular nerve and maxillary artery change their position or course because of hindrance due to the development of the ligament or bar. These bars cause difficulty in surgical approach into para and retropharyngeal spaces using a lateral transzygomatic route through the infratemporal fossa.[31]

Phylogeny of the pterygospinous and pterygoalar ligaments/bony bars

According to some authors, the PSL is derived from the lateral pterygoid muscle whereas others believe that it is derived from the pterygoid fascia.[23] A complete pterygospinous bony bar passes lateral to oval foramen in the typical pithecoid, the nerve passes to the lateral side through an opening of the bar. It is usually incomplete in humans and anthropoids. Its persistence in varying degrees, leads to the existence of pterygoalar and pterygospinous foramina.[3] In skulls of herbivores, carnivores and mature old world monkeys, a wide PSB exists whereas in rodents a small PSB is seen, but it is not usually observed in new world monkeys.[47,24] Therefore, the existence of PSB in humans is regarded as a phylogenic remnant.[7] The ossification of the PSL to form a bony bar was proposed to be controlled by genetic factors and showed variations in frequency in different races. The percentage of persistence of a pterygoalar bar and foramen is variable in human populations of different ethnicities, and are normally present in other animals.[47]

In lemurs, it is deep to oval foramen whereas in epithecoids, it is superficial to the foramen. It occurs in varying degrees of completion in humans and anthropoids. Some authors consider the pterygospinous muscle as a third head of the lateral pterygoid or the muscle that accompanies the PSL could be a remnant of the many pterygoid muscles present in reptiles.[7]

A short lateral pterygoid is seen in platyrrhines, from the middle of the posterior border from which a small spine of Civinini projects backwards. Partially or completely ossified PSL is seen in Aotus genus of monkeys. The lateral pterygoid plate is widely expanded in Tarius, galagids, and lemurids. The ligament may be completely ossified in Old World monkeys. Well-formed foramen of Civinini usually serves for the passage of vessels and nerves to the medial pterygoid muscle. A well-developed spine of Civinini but a moderately developed spine of sphenoid is seen in Great Apes. The sphenoidal spine is well developed in humans, but the lateral pterygoid plate resembles that of Great Apes.[47]

CONCLUSION.

Pterygospinous and PALs and their ossified bony bars are variably related to deep infratemporal structures and may compress them generating various clinical symptoms, which depend on the extent of compression and dimensions of the foramina produced by these ligaments. Anatomical knowledge of these ligaments is important for radiologists, neurologists, dental surgeons and anesthetists during surgical and anaesthetic procedures. It is also interesting to know the role of the ligaments from an anatomical, anthropologic and clinical point of view. These ossified ligaments can be obstacles during a mandibular nerve block, in placing a transcutaneous needle into the foramen ovale, and hinder thermocoagulation procedures. They may obliterate the foramen ovale leading to mandibular neuralgia, may pose difficulties during the normal surgical approach to the retro and parapharyngeal spaces and foramen ovale during medical procedures by obstructing the penetration of the needle through the foramen. Radiological guidance for oval foramen makes puncture easier, more precise and increases procedures success rates. Compression of motor branches of the mandibular nerve results in paresis of the innervated muscles, and compression of sensory branches induce neuralgia or paresthesia, pain and numbness of in the buccal region and tongue, impaired taste and parotid salivary changes.

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