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The pterygoid hamulus: description of its anatomy, topography and clinical implications — a review of literature

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Abstract: The pterygoid hamulus is a bony process that protrudes from the medial pterygoid plate of the sphenoid bone. In spite of its small size and fragile structure, the pterygoid hamulus is an important anatomical structure in many clinical aspects. Orofacial pain may be related to inflammation or irritation of the pterygoid hamulus; if not, other possible explanations should be explored. In addition, the pterygoid hamulus is an important landmark in the oral cavity and is utilized in a number of dental and medical procedures. Thus, the purpose of this work was to review recent studies demonstrating the role and significance of the pterygoid hamulus in clinical practice.

Keywords: sphenoid bone, pterygoid process, hamular process, pterygoid hamulus.

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Introduction

The pterygoid hamulus is a small bony process that resembles a hook and extends bilaterally from the lower end of the medial pterygoid plate of the sphenoid bone. Its length and width are only a few millimetres. According to the nomenclature proposed by Putz and Kroyer the pterygoid hamulus consists of the base, neck and head [1]. Furthermore, the lateral side of the pterygoid hamulus has a groove, therefore it was termed the sulcus hamuli pterygoidei.

The inner anatomy of the pterygoid hamulus reveals oblique osseous trabeculae stretched between thicker medial lamella made of compact bone and thinner lateral lamella [1]. In turn, Sasaki *et al.* found that pterygoid hamulus of the 47-year-old man was composed of mature bone with lamellation and fatty bone marrow [2]. Komarnitki *et al.*, noted that earlier research revealed that the collagen fibers in the medial plate had a more obtuse angle of inclination in relation to the vertical axis than those in the lateral plate [3].

The pterygoid hamulus is located near the area where the soft palate and the palatopharyngeal arch meet, thereby its position can influence the function of the soft palate and surrounding structures. Around the pterygoid hamulus wraps almost at the right angle the tendon of the tensor veli palatini muscle before reaching the soft palate. During contraction and relaxation of the tensor veli palatini its tendon glides around the pterygoid hamulus, thereby it is surrounded by a small bursa, which plays a protective role. The bursa provides lubrication between the tendon of the tensor veli palatini tendon and hamulus, thus diminishing the friction of the tendon against the hamulus, resulting in smooth movement of the tensor veli palatini tendon [4].

Barsoumian *et al.* observed that the dilatator tubae muscle (also termed dilator tubae) rounded the middle one-third of the pterygoid hamulus without making an insertion [5]. According to Rood and Doyle, the dilatator tubae is identified as a medial bundle of muscle fibers within the tensor veli palatini muscle [6]. In this instance, the dilatator tubae may tighten the soft palate, while the adipose tissue, which is situated at the hamulus, may lubricate the tendinous fibers.

Also, the pterygoid hamulus serves as the origin for the pterygomandibular raphe, where the fibers of the buccinator and superior pharyngeal constrictor muscles interdigitate [7]. Furthermore, the lowest and most anterior fibers of the levator veli palatini muscle can originate from the base of the pterygoid process. Hence, the tensor veli palatini muscle assists the levator veli palatini in elevating the palate to occlude and prevent food from entering the nasopharynx during swallowing [1]. These muscles are also involved in speaking, opening and closing the pharyngeal isthmus, and maintaining airway patency [8]. Thus, pterygoid hamuli and nearby muscles facilitate maintaining the functional integrity of the pharynx and soft palate, which disturbance can be observed in cases of pterygoid hamulus fractures. A broken pterygoid hamulus induces detrimental effects on the attached muscles, which play essential roles in velopharyngeal function and middle ear ventilation [9, 10]. Under normal circumstances, the pterygoid hamulus's head is drawn away laterally and caudally, while its body is subjected to increased loading in the medio-dorsal direction [1].

Topography of the pterygoid hamulus

The pterygoid hamulus is located at the transition between the hard and soft palate, posterior and inferior to the palatal bones. The pterygoid hamulus can be palpated behind the 3rd molar of the maxilla, on the posteromedial aspect of the maxillary tuberosity (Fig. 1). However, its precise location is 10 to 16 mm distally from the maxillary tuberosity and posterolaterally from the greater palatine foramen [11]. According to Eyrich *et al.* the hamulus and greater palatal foramen are roughly 15 to 20 mm apart on both sides, with the average distance for the left and right sides being 17.6 mm and 17.7 mm, respectively. The average value of the distance between the left and right pterygoid hamulus and the median plane was roughly 20 mm, with a range of 15 to 27 mm [12].

The pterygoid hamulus orientation in relation to other anatomical structures is referred to as its inclination or angle, measured in both the sagittal and coronal planes. Inclination of the pterygoid hamulus was also classified as anterior or posterior in the sagittal plane, either medial or lateral in the coronal plane [13]. In the sagittal plane, the pterygoid hamulus tended to tilt toward the posterior rather than the front and inclined toward the lateral side in the coronal plane. Although the position of the pterygoid hamulus does not differ significantly with age, according to the findings reported by Orhan *et al.* [14], its inclination decreased with age in the sagittal plane, while in the coronal plane, inclination increased [15]. The average inclination of the pterygoid process in the sagittal plane was found to be 75° and 58° in the coronal plane [1].

The function of the surrounding structures and the soft palate may have an impact on the position of the pterygoid hamulus, as it is located near the place where the palatopharyngeal arch and the soft palate meet [1, 16]. As a result, the stresses applied to the pterygoid hamulus by the attached muscles and ligaments may affect its inclination. Moreover, Krmpotić-Nemanić *et al.* observed that the inclination of the pterygoid hamulus may alter with age [17].

According to Lohokare *et al.*, all of the pterygoid hamuli that were studied were inclined toward the posterior and lateral sides on the sagittal and coronal planes, respectively. As people aged, the inclination of the pterygoid hamuli increased in the coronal plane, while their inclination on the sagittal plane decreased. The left and right sides' inclinations did not differ significantly [15].

In turn, Komarnitki *et al.* found significant differences in the inclination between healthy individuals and those with pterygoid hamulus bursitis syndrome. They regarded that the extensive medial deviation of the pterygoid hamulus in the coronal plane could be a potential pathogenic factor that promotes development of the syndrome resulting from the hamular bursitis [3].

The proper position of the pterygoid hamulus can be also altered in case of cranial deformity with facial asymmetry if compared to individuals with preserved facial symmetry [18]. Thereby, understanding the inclination of the pterygoid hamulus is important for various clinical applications, including diagnosing and surgical planning in this cranial region.

This is due to the fact that the spatial orientation of the pterygoid hamulus can predispose some individuals to developing hamular bursitis or complicate the treatment of certain palatal and dental disorders [4, 19].

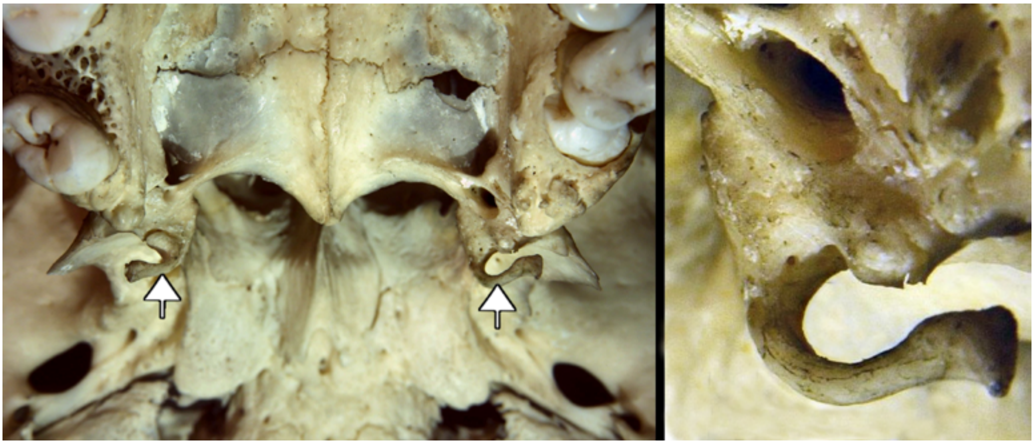

Fig. 1. Topography of the pterygoid hamulus (indicated by arrows) and its appearance in a close-up (demonstrated on the skull from museum collection of the Department of Anatomy, Jagiellonian University Medical College).

Morphometrical variation of the pterygoid hamulus

The pterygoid hamulus is a variable structure that can be assigned to a few fundamental types defined as triangular or slender regarding its shape. Also, terminal portion of the pterygoid hamulus can differ in shape being thin or bulbous. According to Lohokare *et al.*, the triangular shape was more prevalent than the slender type of shape, however they did not find statistically significant variation in the frequency of the triangular versus the slender type of the pterygoid hamulus depending on the sides [15]. A more detailed classification of the pterygoid hamuli proposed Putz and Kroyer [1]. They found that shapes of the pterygoid hamuli may vary from a circular to an elliptic and a drop shape, moreover the transverse form can show a sagittal orientation, a circular shape and a transverse orientation.

Usually, the pterygoid hamulus is a tiny bony structure, which size is usually of a few millimetres on both sides. Despite some individual variations in pterygoid hamulus length between the right and left sides, the studies generally did not find statistically significant differences when comparing the overall populations [20].

The morphometrical studies indicated that the average length of a normal pterygoid hamulus was generally 5–7 mm, and a value greater than 8 mm can be regarded as larger than usual. For instance, Putz and Kroyer found that the average pterygoid hamuli length was 7.2 mm, its sagittal diameter was 1.4 mm, and the transverse diameter accounted for 2.3 mm [1].

The normal length of the pterygoid hamulus may be exceeded with occurrence at 3.5%, as estimated by Malkidou *et al.* Furthermore, they presented a case where the pterygoid hamulus measured 16.4 mm, indicating an excessive length [21].

Shetty *et al.* reported a hamular process with a knife-edge bony projection, measured 18.53 mm [22]. Other case of elongated pterygoid hamulus measuring 13 mm in length had a sickle shape and was noted by Sasaki *et al.* [2]. However, there is no threshold to confirm the hypertrophy of the hamulus taking into account its size [23]. In all cases of elongated pterygoid hamuli, patients may feel the palatal pain associated with mechanical stimulation of the surrounding soft tissues, and suffer other symptoms due to disturbed function of the tensor veli palatini muscle, either other structures attached to the hamulus.

Previous morphometric studies have found statistically significant differences in the length and width of the pterygoid hamulus based on age and sex [15, 16, 24]. With aging there are changes in the morphometric characteristics of the pterygoid hamulus and its relationship to the surrounding structure. According to Mehra *et al.* the length of the pterygoid hamulus increases with age, furthermore males tend to have longer and wider pterygoid hamuli compared to females [24]. Also, Putz and Kroyer concluded that pterygoid hamulus grows in length up to the onset of adulthood and then retains the same length throughout life [1]. In turn, Krmpotić-Nemanić *et al.* noted that children had shorter pterygoid hamuli (3.6 ± 1.5 mm) compared to adults, whose length of the pterygoid hamuli increased to 6.9 ± 1.7 mm but could also decrease to 5.0 ± 1.9 mm in the 60–100-year-old age group [17].

Lohokare *et al.* found that males' right side pterygoid hamuli had the largest length (9.19 ± 2.86 mm), which increased progressively with age up to 50 years and declined up to 60 years. Similarly, the width of pterygoid hamulus was slightly greater in males (1.92 mm) than in females (1.85 mm), increased with age and declined in older people [15]. Orhan *et al.* observed that the patients older than 55 years had shorter pterygoid hamuli (4.50 ± 1.72 mm) than younger patients aged 22 to 55 years (6.38 ± 1.93 mm). Also, the width of the pterygoid hamuli was smaller in the older age group [14].

Age and sex related dependences of the pterygoid hamulus size are probably caused by modifications in the stomatognathic system with aging, tooth loss, and stresses from muscle attachments acting on the pterygoid hamulus [16].

Clinical implications related to the pterygoid hamulus

The morphology of the pterygoid hamulus significantly influences its clinical relevance, due to its involvement in various pathologies affecting the palate and neighboring anatomical structures. The prominent or hypertrophied pterygoid hamulus causes not only irritation and inflammation of the surrounding soft tissues but also may lead to inflammation of the bursa of the tensor veli palatini muscle. Such a pathological condition was termed as the pterygoid hamulus syndrome or pterygoid hamulus bursitis.

The pterygoid hamulus syndrome exists extremely rare in human population. So far, around 40 cases of the pterygoid hamulus syndrome have been reported in the literature (29 cases between the year of 1964 and 2001). The syndrome seems to be an uncommon and underdiagnosed cause of orofacial pain therefore it can be troublesome for a quick diagnosis [25–28].

As previously mentioned, the tendon of the tensor veli palatini is covered by a synovial bursa, and when the attached muscles are contracting, the pterygoid hamulus is subjected to repetitive stress. Thereby, pterygoid hamulus bursitis may develop under such biomechanical conditions. The hamular bursitis can be also initiated by the osteophytes located on the pterygoid hamulus [29]. When the bursa becomes inflamed, this usually leads to localized pain in the soft palate area at the back of the mouth. Additionally, hamular bursitis may cause referred pain that may radiate to the face, temporomandibular joint, and pharynx.

Other clinical features of hamular bursitis may include: strange chronic sensation, swelling or redness of the palatal mucosa overlying the pterygoid hamulus, either the mucosa keratinisation [30]. Therefore, hamular syndrome should be considered in the differential diagnoses of the orofacial pain, which may mimic or coexist with the pain accompanying the impacted teeth, tonsillitis, otitis media, facial neuralgia, and even temporomandibular disorders or Eagle's syndrome [31–33]. This is mainly due to some similar symptoms, such as orofacial pain, trouble swallowing, and jaw discomfort, which can occur in the aforementioned diseases, despite being unique clinical entities with different underlying etiologies [26].

Another source of pain in the hamular area can be a fracture of the pterygoid hamulus, which is considered a surgical procedure rather than a clinical entity. A deliberate fracture of the pterygoid process is not often advised during palatoplasty in order to reduce the strain on the tensor veli palatini [4, 34]. Negative side-effects of the fractured hamulus could be as follows: trouble swallowing, velopharyngeal insufficiency, a disorder that allows nasal air to escape during speech, hence difficulty in producing oral sounds correctly. Because the pterygoid hamulus supports the muscles of the upper pharyngeal sphincter, it helps to maintain the patency of the upper airway. Therefore, a fracture of the pterygoid hamulus can interfere with this function, which may worsen or cause obstructive sleep apnea [35].

Traumatic fractures of the pterygoid process and the pterygoid hamulus have been rarely documented in the literature. For instance, an isolated unilateral fracture of the pterygoid process was reported and discussed by Eriksson and Håkansson [36], and Malkidou *et al.* [21] observed in a dry human skull a fracture of the pterygoid hamulus with bony callus formation.

Nicot *et al.* indicated that a hamulus fracture can accompany a fracture of the pterygoid process, which may happen in association with a mandibular fracture. Additionally, they postulated that a hamulus fracture could be caused by a strong contraction of the pterygoid muscles as a result of facial trauma, as these muscles can generate a significant amount of force [37]. Furthermore, extraction of the third maxillary molar may also cause a fracture of the pterygoid hamulus because it requires forceful surgical techniques in close proximity to the pterygoid hamulus [21].

The pathologies of pterygoid hamulus can manifest other syndromes, which include: bony enlargement and referred palatal pain localized in the hamulus region, worsening of pain during chewing or yawning, and even ringing in the ears (tinnitus), which ceased after surgical resection of the elongated pterygoid hamuli as reported Roode and Bütow [38]. Tinnitus in this case was most likely caused by irritation of anatomical structures around the pterygoid hamulus, which are connected to the auditory tube. The extended hamulus might compress or inflame these anatomical regions, causing tinnitus in certain people. Nevertheless, other case reports do not mention tinnitus as a symptom related to the extended pterygoid hamulus. Thus, tinnitus seems to be an uncommon manifestation that may occur in severe or long-standing cases of the pterygoid hamulus syndrome. Furthermore, Oz *et al.* [35] established that the length of the pterygoid hamulus is inversely associated with sleep apnea severity, and Kuzucu *et al.* [39] found that severity of obstructive sleep apnea was associated with hamulus thickness.

Furthermore, the pterygoid hamulus plays an important role in both prosthodontic and orthodontic practices. The pterygoid hamulus and its adjacent structures contribute in the stability of maxillary dentures by adhesive effect that helps keep dentures in their proper position [40]. The existence of a larger pterygoid hamulus require special attention during making dental impressions because it can create areas of potential distortion in the final impression. Additionally, the pterygoid hamulus plays an important role in pterygoid implant surgery performed in patients with insufficient bone volume in the maxilla [41]. Its precise identification allows for the accurate positioning of implants, and better fitting of prosthetic devices [42].

In orthodontic practice, knowledge regarding the morphology and location of the pterygoid hamulus is indispensable to achieve the best dental arch alignment and proper positioning of teeth. The morphological features of the pterygoid hamulus may impact the mechanics of orthodontic devices such as braces or aligners by changing the distribution of forces during treatment [21, 43]. Understanding the anatomical variations of the pterygoid hamulus facilitates predicting possible complications, including pain or discomfort in the oral cavity associated with the use of orthodontic devices.

Conclusions

Up to date studies indicated that the average length of a normal pterygoid hamulus is generally 5–7 mm, and a value greater than 8 mm can be regarded as larger than usual. However, there is no documented threshold value to confirm the hypertrophy of the hamulus.

Anatomical and clinical studies proved that the pterygoid hamulus is an important bony structure involved in the functioning of the soft palate and serves as an intraoral landmark used in dental and maxillofacial procedures.

Accurate knowledge of the topography and morphological features of the pterygoid hamuli facilitates the proper placement of pterygoid implants, and the positioning of the orthodontic appliances used to correct palatal or dental malformations. Such information is crucial for clinicians diagnosing and treating disorders related to the oropharyngeal region. Thereby, morphometrical analysis of the pterygoid hamulus should be continued as the subject of multidisciplinary studies.

Conflict of interest

The authors declare no conflict of interest or any financial interest associated with the current study.

References

1. *Putz R., Kroyer A.*: Functional morphology of the pterygoid hamulus. Ann Anat. 1999; 181 (1): 85–88. doi: 10.1016/S0940-9602(99)80099-5.
2. *Sasaki T., Imai Y., Fujibayashi T.*: A case of elongated pterygoid hamulus syndrome. Oral Dis. 2001; 7 (2): 131–133. doi: 10.1034/j.1601-0825.2001.0070212.x.
3. *Komarnitki I., Skadorwa T., Chloupek A.*: Radiomorphometric assessment of the pterygoid hamulus as a factor promoting the pterygoid hamulus bursitis. Folia Morphol (Warsz). 2020; 79 (1): 134–140. doi: 10.5603/FM.a2019.0049.
4. *Barchetta N.F., de Oliveira R.L.B., Silveira V.Á.S., Faig-Leite H.*: Clinical and morphofunctional aspects of pterygoid hamulus: literature review. Brazilian Dental Science. 2015; 18 (4): 5–11. doi: 10.14295/BDS.2015.V18I4.1078.
5. *Barsoumian R., Kuehn D.P., Moon J.B., Canady J.W.*: An anatomic study of the tensor veli palatini and dilatator tubae muscles in relation to eustachian tube and velar function. Cleft Palate Craniofac J. 1998; 35 (2): 101–110. doi: 10.1597/1545-1569_1998_035_0101_aasott_2.3.co_2.
6. *Rood S.R., Doyle W.J.*: Morphology of tensor veli palatini, tensor tympani, and dilatator tubae muscles. Ann Otol Rhinol Laryngol. 1978; 87 (2 Pt 1): 202–210. doi: 10.1177/000348947808700210.
7. *Sinnatamby C.S.*: Last's anatomy: regional and applied, 12th edn. Elsevier (Edinburgh). 2011.
8. *Ishijima K., Sando I., Balaban C.D., Miura M., Takasaki K.*: Functional anatomy of levator veli palatini muscle and tensor veli palatini muscle in association with eustachian tube cartilage. Ann Otol Rhinol Laryngol. 2002; 111 (6): 530–536. doi: 10.1177/000348940211100609.
9. *Strini P.J.S.A., Strini P.J.S.A.*: Morphology and fracture effects of the hamulus pterygoid: a literature review of the last 49 years. LAJD. 2021; 3 (1): 475–487. doi: 10.46814/lajdv3n1-041.
10. *Zhao J., Ma H., Wang Y., Song T., Jiang C., Wu D., Yin N.*: Micro-computed tomography-based three-dimensional anatomical structure of the region around the pterygoid hamulus. Cleft Palate Craniofac J. 2022; 59 (7): 918–925. doi: 10.1177/10556656211036302.
11. *Langenegger J.J., Lownie J.F., Cleaton-Jones P.E.*: The relationship of the greater palatine foramen to the molar teeth and pterygoid hamulus in human skulls. J Dent. 1983; 11 (3): 249–256. doi: 10.1016/0300-5712(83)90197-5.
12. *Eyrich G.K., Locher M.C., Warnke T., Sailer H.F.*: The pterygoid hamulus as a pain-inducing factor. A report of a case and a radiographic study. Int J Oral Maxillofac Surg. 1997; 26 (4): 275–257. doi: 10.1016/s0901-5027(97)80867-3.
13. *Nerkar A., Gadgil R., Bhoosreddy A., Shah K., Varma S.*: Cone-beam computed tomography study of morphometric evaluation of pterygoid hamulus. Int J Recent Adv Multidiscip Res. 2017; 4: 2678–2682.
14. *Orhan K., Sakul B.U., Oz U., Bilecenoglu B.*: Evaluation of the pterygoid hamulus morphology using cone beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2011; 112 (2): e48–55. doi: 10.1016/j.tripleo.2011.02.038.
15. *Lohokare A.U., Ul Nisa S., Mhapuskar A., Kannan N., Hiremutt D., Jadhav S.B.*: Cone beam computed tomography study for evaluation of morphology of pterygoid hamulus — a retrospective study. J Indian Acad Oral Med Radiol. 2024; 36 (1): 7–11. doi: 10.4103/jiaomr.jiaomr_80_23.

16. *Komarnitki I., Mankowska-Pliszka H., Ungier E., Dziedzic D., Grzegorczyk M., Tomczyk A., Ciszek B.*: Functional morphometry of the pterygoid hamulus. A comparative study of modern and medieval populations. Anthropol Rev. 2019; 82 (4): 389–395. doi: 10.2478/anre-2019-0029.
17. *Krmpotić-Nemanić J., Vinter I., Marusić A.*: Relations of the pterygoid hamulus and hard palate in children and adults: anatomical implications for the function of the soft palate. Ann Anat. 2006; 188 (1): 69–74. doi: 10.1016/j.aanat.2005.05.005.
18. *Hayashi Y., Tachiki C., Morikawa T., Aihara Y., Matsunaga S., Sugahara K., et al.*: Three-dimensional analysis of the cranial base structure in patients with facial asymmetry. Diagnostics (Basel). 2023; 14 (1): 24. doi: 10.3390/diagnostics14010024.
19. *Charbeneau T.D., Blanton P.L.*: The pterygoid hamulus. A consideration in the diagnosis of posterior palatal lesions. Oral Surg Oral Med Oral Pathol. 1981; 52 (6): 574–576. doi: 10.1016/0030-4220(81)90070-0.
20. *Romoozi E., Razavi S.H., Barouti P., Rahimi M.*: Investigating the morphologic indices of the hamulus pterygoid process using the CBCT technique. J Res Med Dent Sci. 2018; 6 (2): 240–244. doi: 10.5455/jrmds.20186237.
21. *Malkidou N., Chaidas K., Thomaidis V., Vassiou K., Fiska A.*: Pterygoid hamulus: morphological analysis and clinical implications. Cureus. 2024; 16 (3): e55694. doi: 10.7759/cureus.55694.
22. *Shetty S.S., Shetty P., Shah P.K., Nambiar J., Agarwal N.*: Pterygoid hamular bursitis: a possible link to craniofacial pain. Case Rep Surg. 2018; 2018: 5108920. doi: 10.1155/2018/5108920.
23. *Galvez P., Moreau N., Fenelon M., Marteau J.M., Catros S., Fricain J.C.*: Pterygoid hamulus syndrome: a case report. J Oral Med Oral Surg. 2020; 26 (4): 42. doi: 10.1051/mbcb/2020021.
24. *Mehra A., Karjodkar F.R., Sansare K., Kapoor R., Tambawala S., Saxena V.S.*: Assessment of the dimensions of the pterygoid hamulus for establishing age- and sex-specific reference standards using cone-beam computed tomography. Imaging Sci Dent. 2021; 51 (1): 49–54. doi: 10.5624/isd.20200184.
25. *Elmonofy O., ElMinshawi A., Mubarak F.*: Pterygoid hamulus elongation syndrome. Int J Surg Case Rep. 2021; 78: 81–84. doi: 10.1016/j.ijscr.2020.10.035.
26. *Kende P., Aggarwal N., Meshram V., Landge J., Nimma V., Mathai P.*: The pterygoid hamulus syndrome — an important differential in orofacial pain. Contemp Clin Dent. 2019; 10 (3): 571–576. doi: 10.4103/ccd.ccd_796_18.
27. *Shankland W.E. 2nd.*: Pterygoid hamulus bursitis: one cause of craniofacial pain. J Prosthet Dent. 1996; 75 (2): 205–210. doi: 10.1016/s0022-3913(96)90100-6.
28. *Shankland W.E. 2nd.*: Bursitis of the hamular process. Part I: Anatomical and histological evidence. Cranio. 1996; 14 (3): 186–189. doi: 10.1080/08869634.1996.11745967.
29. *Kronman J.H., Padamsee M., Norris L.H.*: Bursitis of the tensor veli palatini muscle with an osteophyte on the pterygoid hamulus. Oral Surg Oral Med Oral Pathol. 1991; 71 (4): 420–422. doi: 10.1016/0030-4220(91)90420-h.
30. *Thukral H., Nagori S.A., Rawat A., Jose A.*: Pterygoid hamulus bursitis: a rare intra-oral pain syndrome. J Craniofac Surg. 2019; 30 (7): e643–e645. doi: 10.1097/SCS.0000000000005700.
31. *Dupont J.S.Jr., Brown C.E.*: Comorbidity of pterygoid hamular area pain and TMD. Cranio. 2007; 25 (3): 172–176. doi: 10.1179/crn.2007.027.
32. *Salins P.C., Bloxham G.P.*: Bursitis: a factor in the differential diagnosis of orofacial neuralgias and myofascial pain dysfunction syndrome. Oral Surg Oral Med Oral Pathol. 1989; 68 (2): 154–157. doi: 10.1016/0030-4220(89)90183-7.
33. *Singh P., Patil P.M., Sawhney H., Patil S.P., Mishra M.*: Giant tonsillolith: a rare oropharyngeal entity. Oral Maxillofac Surg Cases. 2019; 5 (4): 100133. doi: 10.1016/j.omsc.2019.100133.
34. *Kane A.A., Lo L.J., Yen B.D., Chen Y.R., Noordhoff M.S.*: The effect of hamulus fracture on the outcome of palatoplasty: a preliminary report of a prospective, alternating study. Cleft Palate Craniofac J. 2000; 37 (5): 506–511. doi: 10.1597/1545-1569_2000_037_0506_teohfo_2.0.co_2.
35. *Oz U., Orhan K., Aksoy S., Ciftci F.,* Özdoğanoğlu *T., Rasmussen F.*: Association between pterygoid hamulus length and apnea hypopnea index in patients with obstructive sleep apnea: a combined

three-dimensional cone beam computed tomography and polysomnographic study. Oral Surg Oral Med Oral Pathol Oral Radiol. 2016; 121 (3): 330–339. doi: 10.1016/j.oooo.2015.10.032.

36. *Eriksson L., Håkansson H.*: Unilateral fracture of the pterygoid process. Report of a case. Oral Surg Oral Med Oral Pathol. 1979; 47 (2): 127–130. doi: 10.1016/0030-4220(79)90165-8.
37. *Nicot R., Roland-Billecart T., Srouji A., Barry F., Ferri J., Schlund M.*: Lateral pterygoid muscle biometric modifications in pterygoid process fractures associated with mandibular fractures. J Oral Maxillofac Surg. 2020; 78 (12): 2258–2266. doi: 10.1016/j.joms.2020.07.219.
38. *Roode G.J., Bütow K.W.*: Pterygoid hamulus syndrome — undiagnosed. SADJ. 2014; 69 (2): 70–71.
39. *Kuzucu I., Parlak I.S., Baklaci D., Guler I., Kum R.O., Ozcan M.*: Morphometric evaluation of the pterygoid hamulus and upper airway in patients with obstructive sleep apnea syndrome. Surg Radiol Anat. 2020; 42 (5): 489–496. doi: 10.1007/s00276-019-02314-8.
40. *Grasso J.E., Rendell J., Gay T.*: Effect of denture adhesive on the retention and stability of maxillary dentures. J Prosthet Dent. 1994; 72 (4): 399–405. doi: 10.1016/0022-3913(94)90560-6.
41. *Bidra A.S., Huynh-Ba G.*: Implants in the pterygoid region: a systematic review of the literature. Int J Oral Maxillofac Surg. 2011; 40 (8): 773–781. doi: 10.1016/j.ijom.2011.04.007.
42. *Motiwala I.A., Bathina T.*: A radiographic study on pterygoid implants with hamulus as a landmark for engaging the pterygoid plate — a retrospective study. Ann Maxillofac Surg. 2022; 12 (2): 190–196. doi: 10.4103/ams.ams_132_22.
43. *Lee S.C., Park J.H., Bayome M., Kim K.B., Araujo E.A., Kook Y.A.*: Effect of bone-borne rapid maxillary expanders with and without surgical assistance on the craniofacial structures using finite element analysis. Am J Orthod Dentofacial Orthop. 2014; 145 (5): 638–648. doi: 10.1016/j.ajodo.2013.12.029.