Evaluation of the pterygoid hamulus morphology using cone beam computed tomography

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Objective. This study consists of anatomic research of the pterygoid hamulus (PH) using 3D cone beam computed tomography (CBCT) images reconstructed from a volumetric rendering program.

Study design. Three hundred ninety-six sides in the CBCT scans of 198 (115 men and 83 women) patients were retrospectively analyzed. DICOM data of the patients were transferred to a surface-rendering software so as to generate 3D hard tissue surface representations of PHs. The width, length, angle, and the distance between posterior nasal spine and tip of the PH were measured. In addition, the inclinations of PHs were also evaluated in sagittal and coronal planes of the 3D images. Pearson χ² and Student t test were performed for statistical analysis among age, localization, and measurements (P < .05).

Results. The mean PH measurements of left and right sides were 1.72 (SD 0.94) and 1.87 (SD 1.17)-mm width, and the lengths were 5.48 (AD 1.94), and 5.40 (SD 2.0) mm, respectively, with no significant difference (P > .05). All PHs were inclined toward the lateral side in the coronal plane, whereas PHs tended to incline toward the posterior rather than anterior in the sagittal plane (~78%). The results showed no statistically significant differences among age, localization, and measurements of PHs (P > .05).

Conclusions. Knowledge about the morphology of these structures is helpful for the interpretation of imaging and provides valuable information in the differential diagnosis of untraceable pains in the oral cavity and pharynx. Because of potential problems owing to PH morphology and elongation, oral and maxillofacial radiologists should assess the radiographic images thoroughly. (Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;112:e48-e55)

A broad definition of pterygoid hamulus (PH) is a hooklike projection at the inferior end of each medial plate of the pterygoid process. The medial pterygoid plate of the sphenoid bone curves laterally at its lower extremity into a hooklike process, the PH, around which the tendon of the tensor veli palatini (TVP) muscle glides. Although the PH is, because of its bizarre shape, a striking feature of the skull base, it is still an unexplored region on the anatomical map. Only a few studies have been conducted on the morphology of PH; however, because of its close relationship to the maxilla and oropharynx, it is of interest to all disciplines that are involved with this region. The position, length, and inclination of PHs are of great importance for the function of several muscles: tensor veli palatini, palatopharyngeus, and upper part of the upper pharyngeal constrictor, pars pterygopharyngea. These muscles contribute to the separation of the oral from the nasal cavity during sucking and swallowing during growth and development and into adulthood.

Elongation of PH was also associated with a rare syndrome of PH that shows various and complex symptoms in the palatal and pharyngeal regions and also causes pain and discomfort especially during swallowing. The term pterygoid hamulus syndrome was first used to describe a pain in the palatal and pharyngeal regions caused by an abnormally shaped PH by Hjørring-Hansen et al. in 1987 with about 40 cases reported in the literature.

Several studies were conducted on the position and morphology of PH in different populations. According to those studies, the length of the PH was found to be within the range of 4.9 to 7.2 mm. Putz and Kroyer also reported the sagittal and transverse diameter of PH as 1.4 mm and 2.3 mm, respectively, whereas Sasaki et al. also reported an elongated PH of...
13 mm. Recently, it was found that the length increased in adult age and then decreased significantly again in the elderly population. Moreover, all studies reported that the positions of PHs are inclined laterally in the coronal plane.1-2

This information is important especially in tracing an unusual pain in the soft palate and pharyngeal region. Such a symptom in that area may be forming a complex that can include hearing disorders, difficulties in swallowing, headache, pain and clicking in the temporomandibular joints (TMJs), uncontrolled movements of the facial muscles, impacted teeth, trigeminal and glossopharyngeal neuralgia, stylo-hyoid ligament calcification, stylo-mandibular ligament inflammation, tumors, cysts, herpes simplex, infection, otitis media, and so forth; thus, consideration of the PH as a pain-inducing factor should be included in the diagnosis.4,8,11 Therefore, it is important to know the average length, shape, and morphology of PHs for the population that guided us to conduct this research.

The detection of this area can be achieved by radiography (cephalometric radiography, submentovertex, Waters view, and so forth); however, identification of these structures by conventional radiography is exceedingly difficult because of superimposition and distortion. Today, computed tomography (CT) can be performed in axial and coronal planes with 3-dimensional (3D) views for diagnosis and treatment.8 The 3D CT avoids superimposition and problems owing to magnification and offers visualization of the craniofacial structures with more precision than the 2D conventional methods.16-19

Despite various studies that were conducted on shape, length, and position of the PH, the anatomical relations of PH and the surrounding structures are rarely investigated.1,4 Moreover, no studies were found on cone beam computed tomography (CBCT) imaging with generated 3D skull representations using a surface-rendering program to identify and investigate PH. Thus, this study consists of anatomic research of PH using 3D CBCT images reconstructed form a volumetric rendering program.

**MATERIAL AND METHODS**

In the case that guided us to this research, a 26-year-old female was referred to our outpatient clinic because of painful and burning sensations in the soft palate and pharynx of 9 months’ duration. The patient’s history revealed that the symptoms started after traumatic removal of the right maxillary third molar. For this pain, she stated that she was referred to 10 to 15 different consultants, including ear, nose, and throat and maxillofacial surgeons, and various diagnoses were made, such as temporomandibular disorder (TMD) and glossopharyngeal neuralgia. The patient received nonsteroidal anti-inflammatory drugs and also an occlusal splint for TMD. However, the painful sensation was not resolved during the 9 months.

Initial panoramic radiography of the patient showed neither a carious lesion nor any root fragment in the extraction site (Fig. 1) with slight degeneration on the left TMJ condyle. Intraorally, pain and a firm swelling were noted in palpation of the region. A decision was made to perform CBCT to obtain a more precise view of the region. Axial CBCT scan did not demonstrate any abnormality; however, coronal sections showed elongated PH in the right side. The 3D reconstructed CBCT images also showed an elongated PH (9.7 mm in length) with a sickle shape (Fig. 2). Infiltration of local anesthesia to the PH subsided pain; however, the symptoms returned after the anesthetic was metabolized. A diagnosis of hamular pain was made. The patient was
referred for surgery of elongated PH. Following this case, we decided to conduct further research regarding PH morphology in our population.

For this purpose, 396 sides of 198 subjects (115 men and 83 women) ranging in age from 22 to 75 years (mean: 35.54) who had craniofacial CBCT scans were retrospectively investigated. CBCT images were taken for various purposes, such as preimplant imaging, paranasal sinus examinations, or orthodontic purposes. The study’s protocol was carried out according to the principles described in the Declaration of Helsinki, including all amendments and revisions. Only the investigators had access to the collected data. The institutional review board of the faculty reviewed and approved informed consent forms. There was no preference about gender regarding sample choice, however only Turkish patients were included in the study. Only high-quality scans were included. Images of low quality, such as scattering or insufficient accuracy of bony borders were excluded.

CBCT scans were made with a Newtom 3G (Quantitative Radiology s.r.l., Verona, Italy). The imaging protocol used a 9-inch field of view to include the mandibular and maxillary anatomy. X-ray parameters of kV and ma are automatically determined from scout views by the NewTom 3G. Depending on the size of the patient and the extent of beam attenuation, a variation in exposure of up to 40% was possible.

The axial slice thickness was 0.3 mm, and the voxels were isotropic. The axial images were exported as a 512 × 512 matrix in DICOM file format and then were imported in Maxilim software version 2.3.0 (Medicim, Mechelen, Belgium). All constructions and measurements were performed on a 21.3-inch flat-panel color active matrix TFT medical display monitor (Nio Color 3MP, Barco, Belgium) with a resolution of 2048 × 1536 at 76 Hz and 0.2115-mm dot pitch operated at 10 Hz. A consultant experienced in 3D imaging made high-quality 3D hard tissue surface representations computed from the patients’ CBCT data set in several stages similar to previous studies and examined all images.

First, the bone and soft tissue surfaces were segmented by applying a threshold on the acquired image volume of radiographic densities. An attempt was made to reduce noise without reducing actual osseous anatomy. The skulls were rendered as high-quality 3D hard tissue surface representations that were computed from the patients’ CBCT data set. The axial, sagittal, and

Fig. 2. a, Axial CBCT scan showed no abnormality, whereas in b and c, coronal CBCT images showed elongated PH on the right side (arrows) with a normal PH on the left side (arrowhead). d, e, 3D reconstructed CBCT images also showed elongated PH (9.7 mm in length) with a sickle shape (arrow).
coronal CT radiographic slices were also superimposed over reconstructed 3D images (Fig. 3).

Measurements of 3D images were located and marked on the 3D surface-rendered volumetric image using rotation and translation of the rendered images. Landmarks were identified by using a cursor-driven pointer. The width and the length of the PH together with the distance and the angles between posterior nasal spine (PNS) and tip of the PH were measured (Fig. 3, a, b, and c). To standardize the measurements, reference points were chosen. The length measurements were taken from the junction of medial pterygoid plate and PH through the tip, similar to Putz and Kroyer’s study. First a line was drawn from the junction of medial pterygoid plate and PH parallel to the horizontal plane. Following the identification of the midpoint of this line, the length was measured starting from this point to the tip of the PH. The width of the PH was measured as the distance between the most prominence points of the PH in the coronal plane (Fig. 3, c).

In addition, the inclinations of PHs were evaluated in sagittal and coronal planes of the 3D images. The average degrees of inclinations in the sagittal and coronal planes were also calculated by means of the software according to horizontal plane following Putz and Kroyer’s study (Fig. 4). The inclinations in the sagittal plane were also classified visually as anterior and posterior (Fig. 5), whereas inclinations in the coronal plane were classified as lateral or medial. All measurements were done 3 times by the same observer and the mean of these measurements were noted for analysis. The observer also performed the study 2 times with an interval of 2 weeks so as to detect intraobserver variability.

Statistical analyses were carried out using the SPSS 12.0.1 (SPSS, Chicago, IL) software program. To assess intraobserver reliability, Wilcoxon matched-pairs signed-ranks test was used for repeated measurements of the observer. Pearson χ² and Student t test were performed for statistical analysis among age, localization, and measurements (P < .05).

RESULTS

Repeated measurement of CBCTs indicated no significant intraobserver difference (P > .05). Intraobserver consistency was rated at 95% between 2 measurements. A total of 396 left and right sides of PHs were measured in 198 3D CBCT images. The findings are presented in Table I. The mean measurements of both left and right sides were 1.72 (SD 0.94) and 1.87 (SD 1.17)-mm width, respectively whereas the lengths were 5.48 (SD 1.94) and 5.40 (SD 2.0) mm, respectively without any significant difference (P > .05). There were also no statistically significant differences between left and right measurements between posterior nasal spine and tip of the PH of sides (P > .05).

In the coronal plane, it was found that all PHs were inclined toward the lateral side (Fig. 3). However, in
the sagittal plane, 43 (21.7%) PHs were inclined toward the anterior whereas 155 (78.3%) PHs tended to posterior on the left side. Similarly, on the right side, 45 (22.7%) PHs were inclined toward the anterior, whereas 153 (77.3%) PHs tended to the posterior (Fig. 5).

The average inclination in the sagittal plane and in the coronal plane showed no statistically significant difference ($P > .05$) (Table I). The angles between posterior nasal spine and tip of the PH were also measured. The average degree for the left was $33.4^\circ$ (SD 2.34) and $34.3^\circ$ (SD 2.18) for right. Overall results also
Table II. Measurements of PH (mm) and standard deviations (SD) according to age

<table>
<thead>
<tr>
<th>Measurements</th>
<th>22-55 y (mean ± SD)</th>
<th>&gt;55 y (mean ± SD)</th>
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<tbody>
<tr>
<td>Width of the PH in coronal plane</td>
<td>1.85 ± 0.88</td>
<td>1.73 ± 1.07</td>
</tr>
<tr>
<td>Length of the PH</td>
<td>6.38 ± 1.93</td>
<td>4.50 ± 1.72</td>
</tr>
<tr>
<td>Posterior nasal spine to tip of PH</td>
<td>21.73 ± 2.54</td>
<td>20.8 ± 2.85</td>
</tr>
<tr>
<td>The average inclination in coronal plane</td>
<td>53.9° ± 2.18°</td>
<td>52.5° ± 2.17°</td>
</tr>
<tr>
<td>The average inclination in sagittal plane</td>
<td>82.8° ± 2.99°</td>
<td>81.7° ± 3.05°</td>
</tr>
<tr>
<td>Number of inclinations of PH in coronal plane</td>
<td>Lateral</td>
<td>Lateral</td>
</tr>
<tr>
<td></td>
<td>166</td>
<td>32</td>
</tr>
<tr>
<td>Number of inclinations of PH in sagittal plane</td>
<td>Medial</td>
<td>Medial</td>
</tr>
<tr>
<td></td>
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<td>0</td>
</tr>
<tr>
<td></td>
<td>Anterior</td>
<td>Anterior</td>
</tr>
<tr>
<td></td>
<td>39</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Posterior</td>
<td>Posterior</td>
</tr>
<tr>
<td></td>
<td>127</td>
<td>28</td>
</tr>
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</table>

showed no statistically significant differences among gender, localization, and measurements of PHs ($P > .05$).

As a further evaluation, we divided the study group into 2 age groups, 22 to 55 and older than 55 years, so as to detect any differences according to age group. Table II shows the data according to age group. The length of PH differed among the age groups. The patient group older than 55 had shorter PH length than the 22- to 55-year-olds ($P = .054$) (Table II). No further statistically significant difference was found among age and all measurements ($P > .05$).

**DISCUSSION**

Anatomically, the PH and the edge of the medial pterygoid plate immediately superior to the PH, give rise to the origin of the superior constrictor muscle of the pharynx. The palate pharyngeus muscle originates in layers from the PHs, as well as from the border of the hard palate, and from fibers of the levator veli palatine muscle (LVP). It is generally stated that the lowest and most anterior fibers of LVP arise from the base of the pterygoid process and reach up to a little and beyond the base of the PH. In addition, TVP originating from the scaphoid fossa, the spine of palatal aponeurosis, and the lateral wall of the cartilaginous auditory tube winds its tendon around the PH in a groove with a synovial bursa between the tendon and the bone, inserts soft palate. The separation of the oral from the nasal cavity is accomplished by the elevation of soft palate with constriction of these muscles. As the tendon of the TVP winds around the PH, a synovial bursa is situated between the tendon and the bone. This bursa within the sulcus hamulus is responsible for the gliding of the tendon. It reduces friction caused by movement of the tendon of the TVP muscle around the PH.

The position, inclination, and especially the length of PHs are of great importance for the function of the muscles that are located here. When these muscles contract, the nasal and oral cavities separate from each other during swallowing and sucking. This separation is accomplished by the evaluation of soft palate following LVP contraction and Tubar part of TVP for stretching the palatal aponeurosis. TVP also produces tension and elevation of soft palate, which the Tubar part is fixed to the hamulus. The position and morphology of PH are closely related to TVP function, which directly affects the width of the hard plate during swallowing. The inclination of the PH is also responsible for better tension of palatal aponeurosis. Krmpotić-Nemanić et al. pointed out that if the hamulus remains short as in newborns, the surrounding muscles do not have firm support, which leads to uncontrolled narrowing of the upper pharynx, thus causing snoring and sleep apnea.

Besides, the elongated PH can also be the reason for pain and discomfort in the soft palate and pharynx. Such cases have been previously reported. Gores was the first to report the presence of pain caused by a long PH. The term pterygoid hamulus syndrome was then used to describe a pain in the palatal and pharyngeal regions with about 40 cases reported in the literature.

There is no consensus for the etiology of this syndrome. Previously, several etiologic factors stated bursitis of TVP or an osteophyte, elongation of PH, or consistent minimal trauma to the overlying structure. The trauma from swallowing a large bolus of food or from an overextended denture, anesthesia intubations, trauma during tooth brushing, bulimic patients, and “fellatio” in child abuse seem to be the cause of this syndrome. In our case, the patient had her third molar extracted and the symptoms started after this operation. Patients suffering from this syndrome have clinical signs, including pain and sensation of strangeness, burning and swelling of the hard/soft palate, elevated noise sensitivity, dysphagia, dysfunction of muscles, and difficulty in swallowing. Clinically, the PH region usually appears erythematous; sometimes the PH can be palpated as firm swelling or recognized as an enlargement under the mucosa of the soft palate. Further, the PH may have tenderness to palpation, which will be eliminated after anesthetic infiltration of the area. In our case, no erythematous appearance was seen; however, a firm swelling was noted and pain subsided after anesthetic infiltration.

The differential diagnosis of pain in the hard/soft palate and pharynx should include tumors, cysts, infections, foreign bodies, elongated styloid syndrome, third
molar eruption, TMJ diseases, muscular dysfunction, and also elongated PH.4,10,11

Several studies were conducted on the morphology of PH in different populations. Eyrich et al.5 found the mean length of the left hamulus to be 5 mm and the right to be 4.9 mm. Putz and Kroyer1 reported the average length to be 7.2 mm and the sagittal and transverse diameter to be 1.4 mm and 2.3 mm, respectively. Sasaki et al.10 also reported an average PH length of 6.8 mm (SD 1.4 mm). Our results showed the mean length of PHs for left and right sides were 5.48 (SD 1.94) and 5.40 (SD 2.0) mm, respectively which is similar to other studies.1,4,10 There was no significant difference according to gender and location. Sasaki et al.10 reported an elongated PH case of 13 mm. Our longest PH case was 10.9 mm in a male patient.

Recently Krmpotic-Nemanic et al.2 conducted an extensive study on PH. They investigated the PH among 3 age groups: children (0-9), adults (21-59), and elderly (60-100). They found that children had the shortest PH length, on average 3.6 mm. The length increased in adults (6.9 mm) and then decreased significantly again to 5.0 mm in the elderly group. They also found no statistical difference for gender and for left and right sides.

Although no statistically significant difference was observed between the age groups, the P value was .05. From a numerical point of view, it can be concluded that older patients had shorter PH length than the younger patients. This is in line with Krmpotic-Nemanic et al.5 study, but does not coincide with Putz and Kroyer’s1 study, which reported that the PH increases in length to the beginning of adulthood, and thereafter remains unchanged throughout life.

There was only one study regarding the width and the inclination of the PH.1 Putz and Kroyer1 measured the sagittal diameter of PH as 1.4 mm, which is consistent with our width (sagittal diameter) measurements: 1.72 (SD 0.94) and 1.87 (SD 1.17) mm for left and right, respectively. The inclinations in their study were 75° in the sagittal plane and 58° in the coronal plane, which is also similar to our results (Table II). Each hamulus in this study was inclined laterally, as in previous studies.1-2 The results showed no statistically significant differences among gender, localization, and measurements of PHs (P > .05).

The elongated PH can be responsible for atypical pain in the soft palate and pharynx region. Radiographs of the PH and pterygomaxillary region should be obtained for the findings of osteophytes or hamular fracture or for any other abnormality. The detection of this area can be achieved by radiography (cephalometric radiography, Submentovertex, Waters view, conventional tomography). However, identification of these structures by conventional radiography is exceedingly difficult because of superimposition and distortion. Today, CT can be performed in axial and coronal planes with 3D views for diagnosis and treatment of this region.7-8,24 The 3D CT avoids the superimposition and problems owing to magnification and offers visualization of the craniofacial structures with more precision than the 2D conventional methods.17,19,25 Despite these advantages, the effective dose of CT is much higher than the conventional radiographs and also expensive procedures and scanners are not easily accessible.19,26,27

In the past decade, CBCT was proposed for maxillo-craniofacial imaging.28-31 The advantages of this imaging modality are the following: lower radiation dose than traditional CT, the possibility of individualized overlap-free reconstructions, and DICOM data can be imported and exported for other applications.28 Dental CBCT can be recommended as a dose-sparing technique compared with alternative standard medical CT scans for common oral and maxillofacial radiographic imaging tasks. Effective dose (ICRP 2007) from a standard dental protocol scan with the traditional CT was from 1.5 to 12.3 times greater than comparable medium field of view dental CBCT scans.32 It was also stated that effective dose and dose to the main portions of the head and neck were higher for traditional CT than for CBCT. Image quality of CBCT was judged to be equivalent to that of traditional CT for visualizing the maxillofacial structures.33-37

From the radiation point of view, CBCT examinations can be used instead of CT to evaluate this region. When 3D imaging is required to visualize anatomic structures, such as processes of sphenoid bone, hard/soft palate, and oropharynx, CBCT should be preferred over a CT image.

CONCLUSIONS

Knowledge about the morphology of these structures is helpful for the interpretation of imaging and provides valuable information in the differential diagnosis of untraceable pains in the oral cavity and pharynx. Because of potential problems owing to PH morphology and elongation, oral and maxillofacial radiologists should assess the radiographic images thoroughly. Similar studies will provide useful information to better understand the anatomy and diseases regarding the PH.

REFERENCES
with special reference to its origin and insertion. Cleft Palate Craniofac J 2004;41:474-84.


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