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Original article

Vomero-premaxillary joint: A marker of evolution of the species☆

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ABSTRACT

Objective: According to evolutionary developmental (evo-devo) theory, the vomers are bones derived from the secondary palate. Growth of the palatine processes of the maxillae, including the precursors of vomer bones, results in midline fusion posteriorly to the primary palate, which forces the ascension of the vomer bones towards the primary nasal septum, formed by septal cartilage and the perpendicular plate of the ethmoid. According to this hypothesis, the anterior border of the vomer articulates with the posterior surface of the premaxilla in the incisive canal (IC).

Material and method: The objective of this retrospective study was to measure the degree of impaction of the anteroinferior angle of the vomer in the IC on CT scans showing a non-deformed nasal septum. Thirty-two out of a series of 506 nasal sinus CT scans were used to obtain measurements on coronal sections of non-deformed septa through the IC.

Results: Thirty-one of the 32 vomers were impacted in the IC. In the case of a Y-shaped vomer ($n = 26$), 43% of the length of the vomer was impacted in 41% of the length of the IC. In the case of I-shaped vomers ($n = 6$), 34% of the length of the vomer was impacted in 41% of the length of the IC. The only vomer that did not impact into the IC was Y-shaped.

Conclusion: Impaction of the vomer in the IC posteriorly to the premaxilla can be explained by the evo-devo concept of the formation of the nasal cavities. In contrast, the classical embryological description of the formation of the nasal septum cannot provide an explanation for impaction of the vomer.

1. Introduction

According to classical embryology, the formation of the secondary palate results from elevation followed by midline fusion of the palatine processes of the maxillae, posteriorly to the primary palate, from which they remain separated by the anterior palatine foramen or incisive canal. Endochondral ossification of the mesenchyme of the ventral portion of the fused palatine processes results in the formation of the hard palate, while the mesenchyme of the dorsal portion undergoes myomatous differentiation resulting in the formation of the soft palate [1,2]. The nasal septum results from midline proliferation of ectoderm and mesoderm of the roof of the frontonasal process and the medial olfactory process, which advances caudally to fuse with the palatine processes and sagittally separate the two nasal cavities, which open into the pharynx via the choanae. Neither the anatomical formation of the secondary palate formed by the palatine processes of the maxillae as well as the horizontal palatine processes, nor the formation of the nasal septum formed by the septal cartilage, the perpendicular plate of the ethmoid and the vomer can be clearly explained by classical embryology.

According to evolutionary developmental (evo-devo) theory [3], the vomers are bones of the secondary palate which, following development of the palatine processes of the maxillae, are forced to fuse in the midline posteriorly to the primary palate, which constrains their ascension towards the nasal cavity to form the inferior or respiratory part of the nasal septum underneath the olfactory septum. The olfactory septum is formed by the perpendicular plate of the ethmoid (the bone of the skull base that houses the olfactory mucosa derived from invagination of the centre of the olfactory placodes) and the septal cartilage (which differentiates from the median wall separating the zones of invagination of the olfactory placodes). According to evo-devo theory, ascension and fusion of the palatine processes of the maxillae is followed by the vertical emergence of precursors of the vomers above the midline fusion of the palatine processes, posteriorly to the primary palate.

The working hypothesis of this study was that the vomero-premaxillary joint could provide evidence in support of the evo-devo theory of development of the human palate, as, according to the classical view of the nasal septum that separates the nasal cavities by joining the palate to the roof of the nasal cavities and

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which subsequently undergoes differentiation into its three tissue components (septal cartilage, perpendicular plate of the ethmoid and vomer), there is little reason for the vomers to even partially enter the incisive canal. In contrast, according to the evo-devo theory, the palatine processes of the maxillae (the precursors of which already contain the precursors of the vomers) force the vomers to fuse in the midline and then develop vertically behind the primary palate. Ascension of the vomers therefore occurs as a result of compression behind the primary palate and can result in impaction of the anteroinferior angle of the vomer in the incisive canal.

The objective of this study was to measure the length of the vomer and the proportion of this length impacted in the incisive canal on coronal CT sections through the incisive canal.

2. Material and method

We retrospectively reviewed adult nasal sinus CT scans available in our university hospital imaging database, performed between January 2013 and June 2014. These scans corresponded to native multiplanar CT scans with bone window settings. CT scans were performed on Aquilion One Toshiba® (0.5 mm native sections) and Aquilion 64 Toshiba® scanners (1 mm native sections). Images were then reconstructed and analysed on contiguous 1.5 mm thick sections on a Vitrea console (Vitrea Console, Vitrea image processing software, Vital Images, Minnesota, USA).

The main inclusion criterion was a non-deformed nasal septum. The septum was considered to be non-deformed when it met the following criteria analysed on two types of sections.

On a standard coronal section with, by definition, a plane of section perpendicular to the hard palate, protrusion of the septum into the left or right nasal cavities did not exceed a distance of 3 mm with the vertical line through the anterior nasal spine and the insertion of the perpendicular plate underneath the skull base, no signs of septal disruption (such as a chondrovomerine spur) and a straight vomer.

On a sagittal section, the three elements (septal cartilage, perpendicular plate of ethmoid and vomer) had to be visible on the same section passing anteriorly through the incisive canal, posteriorly through the odontoid process and superiorly through the insertion of the perpendicular plate of the ethmoid underneath the skull base (Fig. 1A).

All CT scans revealing opacification of the nasal cavities and/or the ethmoid bone and CT scans performed in patients with a history of trauma or nasal surgery or edentulous subjects were excluded from the study.

The shape of the vomer was classified into three types: Y-shaped when a vertical segment and two wings were visualized, I-shaped when only the vertical segment of the vomer was visualized, V-shaped when only two wings were visualized with no vertical segment. Several parameters were measured: length of the right and left vomerine wings when they were visible, length of the vertical segment of the vomer and length of the incisive canal (Fig. 1B). The following proportions were calculated from these measurements: the proportion of the vertical segment of the vomer impacted in the incisive canal and the proportion of the incisive canal occupied by the vertical segment of the vomer.

When visualized in the coronal plane, the incisive canal has a dumbbell shape. By convention, it was decided, for this study, to measure the length of the incisive canal by only taking into account the straight portion of this canal. Only the portion of the vertical segment of the vomer impacted in this straight portion of the incisive canal was considered to be impacted in the incisive canal (Fig. 1B).

As the incisive canal is oblique in the standard coronal plane, the same measurements and calculations of proportions were then performed in a modified coronal plane through the axis of the incisive canal in order to ensure that measurements in the axis of the incisive canal did not differ from those available in routine clinical practice using the standard coronal plane. In this plane, the incisive canal is visualized as a vertical cylindrical structure, allowing the greatest length of the vomer, the greatest length of its wings and the real length of the incisive canal to be determined on a single section (Fig. 2).

3. Statistics

Statistical tests were performed with SPSS software (version 15.0 for Windows).

Quantitative numerical data are expressed in millimetres (mean, standard deviation). Student's t-test was used for comparisons of means after verification of the equivalence of variances by Levene's test. Only Y-shaped vomers were taken into account to determine the length of vomerine wings. A P-value less than or equal to 0.05 was considered to be significant.

4. Results

Thirty-two CT scans with a non-deformed nasal septum out of a series of CT scans were included in this study. Table 1 presents the results of measurements performed on standard coronal sections.

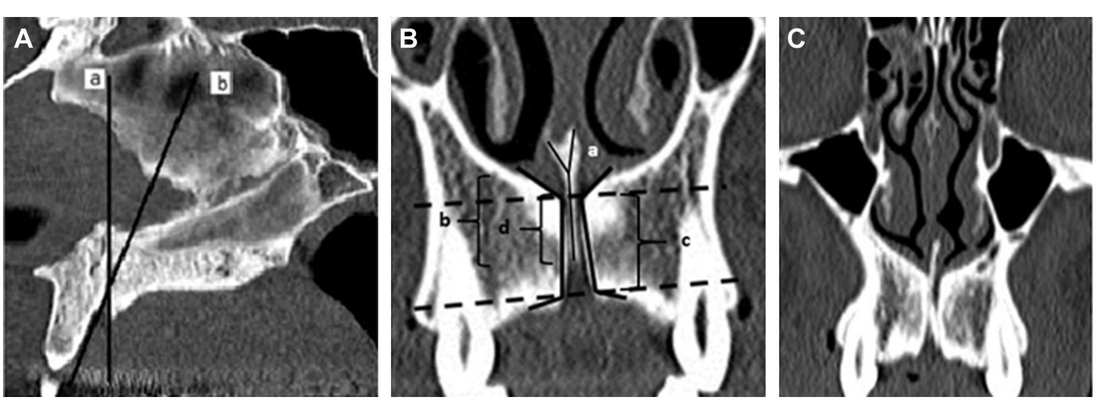

Fig. 1. A. Sagittal section of a non-deformed nasal septum through the incisive canal anteriorly, the skull base insertion of the perpendicular plate of the ethmoid superiorly and the odontoid process posteriorly, aligning the three structures composing the nasal septum: (a) axis of the standard coronal section; (b) axis of the modified coronal section through the incisive canal. B. Measurements on coronal sections through the incisive canal (IC): (a) Length of the right and left vomerine wings (mm); (b) length of the vertical segment of the vomer (mm); (c) length of the IC (mm) (the dumbbell-shaped incisive canal is indicated by solid black lines; by convention in this study, length "c" corresponds to the straight segment); (d) length of the vomer impacted in the incisive canal. C. Example of an I-shaped vomer (no vomerine wing visible).