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A radiological anatomic study of the cribriform plate compared with constant structures*

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SUMMARY

***Background**: Understanding of the anterior skull base anatomy is crucial to avoid intracranial violations during endoscopic surgery. The aims of this study were to define the normative data about cribriform plate depth and the relationship between this dimension and the measurements of the adjacent anatomical structures such as middle turbinate length, maximal vertical orbital height and distance between the ethmoid roof and the nasal floor.*

***Patients and Methods**: Paranasal computerized tomographic scans of 136 healthy adults were included into the study. The cribriform plate depth compared to the ethmoid roof, and the adjacent anatomical structures mentioned above were measured bilaterally.*

***Results**: The maximal vertical orbital height was detected as the most constant anatomic measurement. We found the mean level difference between the ethmoid roof and the cribriform plate as 6.1 ± 2.3 (range 1-12 mm) on the left side and 6.1 ± 2.2 (1-15 mm) on the right side. The middle turbinate was significantly longer in the Keros Type I group than in the other groups ($p<0,05$). Furthermore, the distance between the ethmoid roof and the nasal floor was lowest in the Keros Type I group ($p<0,01$). The distance between the ethmoid roof and the nasal floor was statistically higher in Keros group 3 among all groups ($p<0,01$). The deeper the cribriform plate, the higher the nasal cavity.*

***Conclusion**: To the best of our knowledge, our study has a unique feature by including the data of the constant anatomical structures comparing with the cribriform plate depth. Since in the group with excessive cribriform plate depth, the middle turbinate was short, care should be taken especially during middle turbinate resections.*

Key words: cribriform plate, ethmoid roof, orbit, nasal cavity height, middle turbinate length, constant anatomic structures.

INTRODUCTION

The surgeons dealing with endoscopic sinus surgery should understand the crucial complex anatomy of the anterior cranial base to avoid the intracranial violation during endoscopic surgery. The cribriform plate forms the vault of the nasal cavity and is located lower than the ethmoid roof. The medial extension of the orbital plate of the frontal bone forms the ethmoidal roof. The ethmoidal roof joins to the lateral lamella of the cribriform plate medially and ascends like a dome laterally. The greater difference between the depth of the cribriform plate and the fovea ethmoidalis, the wider relationship between the uppermost ethmoidal cells and endocranium will be. The ethmoid roof is formed by the frontal bone and is located 7- 16 mm superiorly to the cribriform plate (Keros, 1962; Lang, 1998). The relationship between the olfactory fossa and the ethmoid roof was classified into three types by Keros (1962). According to the Keros classification, the difference between the height of the cribriform plate and ethmoid roof is 1 to 3 mm in Keros Type I, 4-7 mm in Keros Type II and more than 8 mm in Keros Type III (Keros, 1962).

The computerized tomographic (CT) evaluation of the paranasal sinuses providing detailed knowledge of the paranasal sinus anatomy is a must and the gold standard method prior to endoscopic surgery. The coronal CT of the paranasal sinuses additionally evaluates the anterior skull base and the relationships between the paranasal sinuses and the central nervous system effectively.

The aims of this study were to define the normative data about the cribriform plate depth in comparison to the ethmoid roof and the relationship between this dimension and the measurements of the adjacent anatomical structures such as middle turbinate length, maximal height of the orbit at the vertical plane and distance between the ethmoid roof and the nasal floor.

PATIENTS AND METHODS

Paranasal sinus CT scans of 136 (75 females, 61 males) healthy

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Table 1. The measurements of some anatomic structures using paranasal sinus computed tomography in coronal position. Values are in millimeters.

Cribriform plate depth		The length of the middle turbinate		The maximal height of the orbit		Distance between the ethmoid roof and the nasal floor	
Left side	Right side	Left side	Right side	Left side	Right side	Left side	Right side
6.1±2.3	6.1±2.2	26.2±3.9	26.3±4.4	39.2±3.8	39.1±3.6	52.3±5.1	51.8±5.2

Table 2. The measurements of some anatomic structures using paranasal sinus computed tomography in the coronal position according to the Keros classification. (n: number of cases). Values are in millimeters

	The length of the middle turbinate		The maximal height of the orbit		Distance between the ethmoid roof and the nasal floor	
	Left side	Right side	Left side	Right side	Left side	Right side
KEROS I [n:11 (%8.1)]	27.7±3.8	28.5±4.2	39.9±8.9	39.7±8.3	47.8±3.7	47.1±3.0
KEROS II [n:81(%59.6)]	26.1±3.3	25.9±4.4	39.0±3.3	39±3.2	51.5±4.6	51.2±4.8
KEROS III [n:44(%32.3)]	26.0±4.8	26.5±4.4	39.2±2.6	39.3±2.4	54.9±5.1	54.2±5.1

Table 3. The distribution of asymmetry seen in our cases according to the Keros classification (**p<0.01).

	1 mm	2 mm	more than 2 mm	Total
KEROS I	4	-	-	4 (%36.7)
KEROS II (Asymmetry range 1-4 mm)	20	15	6	41 (%50.6)
KEROS III (Asymmetry range 1-6 mm)	3	12	**10	25 (%56.8)

adult volunteers were included in the study. The mean age was 34.1 years old (between 18-71 years). The mean age of the 61 males was 35.2 (range: 18-71) and 75 females was 33.2 (range: 18-65). Patients with massive nasal polyposis, benign or malign tumors, previous nasal surgery or trauma were excluded.

CT examinations were performed on General Electric CT ProSpeed and Philips CT Secura. Scans were obtained by 3 mm increments from the glabella to the posterior boundary of the sphenoid sinus in the coronal plane. The paranasal coronal CT scans were evaluated for measurements. The cribriform plate depth compared to the ethmoid roof, maximal height of the orbit in vertical plane, the middle turbinate length, and the distance between the ethmoid roof and the nasal floor at the anterior ethmoidal region were measured bilaterally. As already determined by Meyers and Valvassori (1998), the horizontal foveal plane, which passes medially between the point of the junction roof and the medial orbital walls laterally through the orbit, was used for the determination of the height of the fovea ethmoidalis (Figure 1). Then, the data of the cribriform plate depth were classified according to the Keros classification system (Keros, 1962).

Statistical methods

The possible relationships between the cribriform plate depth and the other anatomical measurements were analyzed statistically by the unpaired t-test. The significance of differences of the data from male subjects and female subjects; from the left and right sides and from the Keros groups was compared statistically by the unpaired t-test with equal variances. The incidences of the asymmetry in the Keros groups were also compared using the chi-square test. In all analyses, the SPSS 5.0 statistical analysis program was utilized and $p<0,05$ was defined as the level of significance.

RESULTS

Since, no statistical significant gender difference between the measurements obtained from females and males of the cribriform plate depth, middle turbinate length, distance between the ethmoid roof and the nasal floor and orbital height ($p>0,05$) were found, the results were evaluated for the overall data of the 136 cases. The mean values and standard deviations of the measurements are given in Table I. The mean values and standard deviations of the measurements are given in Table 2 according to the Keros classification. No statistical significant differences were found between the right and left sides' cribriform plate depth, orbital height, distance between the ethmoid roof and the floor of nasal cavity and middle turbinate lengths after the Keros classification ($p>0,05$).

The asymmetry of the opposite side cribriform plates were also evaluated. Table 3 shows the incidence of asymmetry of our subjects grouped according to the Keros classification. For

Table 4. The measurements of some anatomic structures using paranasal sinus computed tomography in the coronal position according to the Keros classification. (n: number of sides, * $p<0.05$, ** $p<0.01$). Values are in millimeters.

	The length of the middle turbinate	The maximal height of the orbit	Distance between the ethmoid roof and the nasal floor
KEROS I (n:22)	*28.1±3.9	39.8±8.4	**47.5±3.3
KEROS II (n:162)	26.0±3.9	39.0±3.2	51.4±4.7
KEROS III (n:88)	26.2±4.6	39.2±2.5	**54.6±5.1

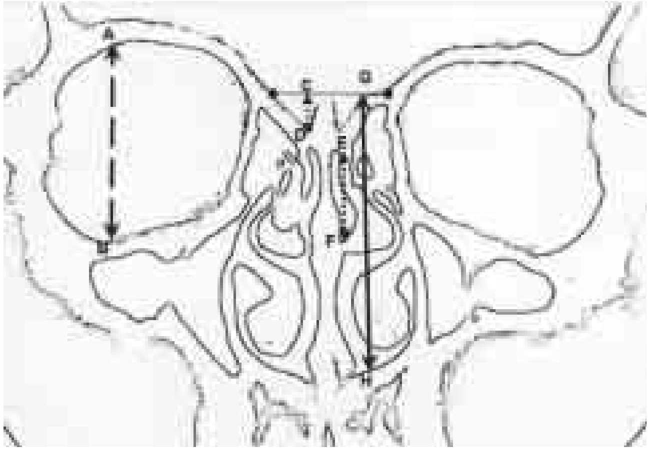

Figure 1. Anatomic measurements performed in our report are shown on a drawing paranasal sinus tomography obtained in the coronal position.
A-B: Maximal height of the orbit in the vertical plane
C-D: Olfactory fossa depth
E-F: Middle turbinate height
G-H: Distance between the ethmoid roof and the nasal floor

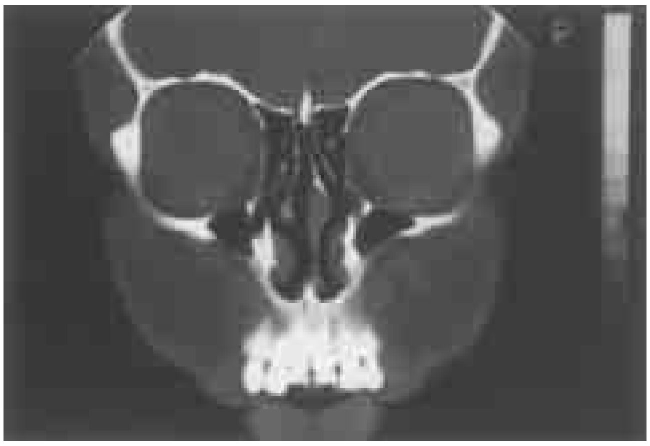

Figure 2. Type I cribriform plate according to Keros classification.

more than 2 mm asymmetry, the Keros 3 group showed a statistical difference when compared to the other groups ($p<0,01$). Since, no difference was found between the data of the opposite sides obtained from the groups, they have been unified at each Keros group (Table 4). The maximal orbital height in the vertical plane was detected as the most constant anatomic measurement. The middle turbinate was significantly longer in Keros Type I group compared to the other groups ($p<0,05$). Furthermore, the distance between the ethmoid roof and the nasal floor was the lowest in the Keros Type I group ($p<0,01$). The distance between the ethmoid roof and the nasal floor was statistically higher in Keros group 3 among all groups ($p<0,01$).

DISCUSSION

The frontal bone is thick and dense in the ethmoid roof area. But medially, the transition from the thick bony part of the frontal bone to the thinner lamellae of the ethmoid is observed (Stammberger, 1991). The thinner medial wall of the ethmoid roof is formed by the lamina lateralis of the lamina cribrosa. Because of the lateral lamella of the lamina cribrosa is the thinnest part of the ethmoid roof, the intracranial violation risk is higher in that area during endoscopic surgery. The lateral lamella is seen as a long segment in cases with a deeper cribriform plate. Only paranasal sinus CT-scans taken in the coronal plane can provide adequate information about the patient's individual conditions and variations (Stammberger, 1991).

Keros introduced a classification system for the depth of the cribriform plate in comparison to the ethmoid roof in 1962 (Keros, 1962). The relationship between the olfactory fossa and the ethmoid roof was classified into three types by Keros (1962). Type I relationship shows that the olfactory fossa is flat and the lateral lamella is higher (Figure 2). In Type II, the lateral lamella is higher and the olfactory fossa is deeper (Figure 3). The Type III, characteristics are a considerable high ethmoid roof and a deeper olfactory fossa (Figure 4). The Type III relationship is the most dangerous type for endoscopic sinus surgery because of the high penetration possibility through the lateral lamella of the lamina cribrosa. The more asymmetry in ethmoid roof height, the higher incidence of intracranial penetration is on the side where the position of the ethmoidal roof is lower (Dessi et al., 1994).

The variability in the depth of the cribriform plate may be

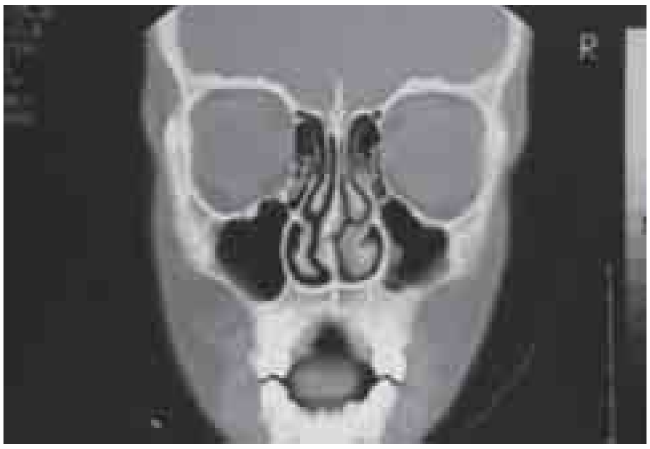

Figure 3. Type II cribriform plate according to Keros classification.

Figure 4. Type III cribriform plate according to Keros classification.

related to developmental factors. Krmpotic-Nemanic et al. (1997) studied 150 skull specimens from fetal to perinatal life, 150 skull specimens from newborn to 30 years of age and 100 skull base specimens from 30 to 90 years of age. The ethmoid labyrinth development was relatively slow in the first decade of life. The cribriform lamina first lowers in its frontal part because of the development of the frontal bone. The lowering of the cribriform plate continues in an anteroposterior direction depending on the pneumatisation degree of the frontal sinus (Krmpotic-Nemanic et al., 1997). The orbital parts of the frontal bone were formed by the cerebral and orbital lamina. The cerebral lamina had the tendency to grow more quickly during the first decade of the life. The intensity of pneumatisation of the ethmoid labyrinth and the frontal sinus determines the relations of the subunits of the anterior cranial fossa (Krmpotic-Nemanic et al., 1997).

The literature contains large series of papers about the cribriform plate depth and our results are in accordance with them. The depth of the cribriform plate compared to the ethmoid roof was found between 4 mm to 7 mm in 70.2 % of the cases where the right side was a little bit lower than the left side in the Keros' study (Krmpotic-Nemanic et al., 1997). Lang (1998) observed that the average of the depth was 5.03 mm (range 0-15.6 mm). Meloni et al. (1992) found that this measurement was 5.94 mm on average with a range from 1.3 mm to 17 mm in 106 patients. Arslan et al. (1999) detected a mean difference between the ethmoid roof and the vault of the nasal cavity of 8 mm (range 2-14 mm) on the right side and of 9.5 mm (range 3-16 mm) on the left side. We found the mean level difference between the ethmoid roof and the cribriform plate as 6.1 ± 2.3 (range 1-12 mm) on the left side and 6.1 ± 2.2 (1-15 mm) on the right side. These data showed no statistical significant difference between the opposite sides.

In our study, as defined by Meyers and Valvassori (1998), we used the horizontal foveal plane which passes medially between the point of the junction roof and the medial orbital walls laterally through the orbit for determination of the height of the fovea ethmoidalis.

Besides the amount of the depth of the cribriform plate, the asymmetry between the opposite sides was found investigated by several authors. Many reports indicated that the mean cribriform plate depth on the right side was lower than the left side (Keros, 1962; Teatini et al., 1987; Meloni et al., 1992; Dessi et al., 1994; Lebowitz et al., 2001). Lebowitz et al. (2001) evaluated the fovea ethmoidalis for height and contour asymmetry on the left and right sides and found that in the 86 of the 200 (43%) cases, the foveae of both sides were symmetric in height and contour. Nineteen cases (9.5%) showed a height asymmetry. Twelve (63.2%) of them had low fovea on the right side and seven (36.8%) of them had low fovea on the left side. The mean difference in height was 2.53 mm (range 1-4mm). Ninety-six (48%) of the CT scans demonstrated contour asymmetry of the fovea ethmoidalis. Dessi et al. (1994) found asymmetry in 15 of 150 CT scans (10%) in a prospective study. In 13 cases, the right fovea ethmoidalis was 2-7 (mean 3.9 mm) millimeters lower than the left one. They found that the cribriform plate was 2-7 millimeters (mean 5 mm) lower than the ethmoidal roof. But Jones et al. (2002) measuring cribriform plate height relative to a supraorbital horizontal line did not find any statistically significant difference between the right and the left sides. Their results showed that the mean depth of the cribriform plate to supraorbital horizontal line was 14.3 mm. The clinical value of this method for the measurement of the depth of the cribriform plate to supraorbital horizontal line is limited. The mean level difference between the ethmoid roof and the cribriform plate is more meaningful for endoscopic sinus surgery to avoid the intracranial violation. We found a left and right side asymmetry between the cribriform plate and the ethmoid roof in 70 of the 136 cases (51,5%) with a statistically insignificant distribution for the sides (36 at the left and 34 at the right side).

To the best of our knowledge, our study has the unique feature to include the data of the constant anatomical structures compared with the cribriform plate depth. The maximal orbital height in the vertical plane was detected as the most constant anatomic measurement. The variability of the size of the well-known and every-day confronted structures was reported for the first time. The deeper the cribriform plate, the higher the nasal cavity. The middle turbinate was longer in height in shallow cribriform plates. The discussion of these data from the practical viewpoint is limited to speculate that nobody's nose is the same. But, since in a patient with an excessive cribriform plate depth, the middle turbinate was short, care should be taken especially during middle turbinate resections.

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