

## Branching of the foramen rotundum. A rare variation of the sphenoid

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### Abstract

The human orbit communicates with the middle cranial fossa through several canals and openings. Some of them (optic canal, superior orbital fissure) are constant, others (meningo-orbital foramen, Warwick's foramen, metoptic canal) are less frequent. Here we report a rare variation of the foramen rotundum which, opening into the orbit with a branching canal, represented a further connecting pathway between the orbit and the middle cranial fossa. Such variation was detected in about 1.06% of individuals and it was almost always located on the right side. Only in one cases it could be found left-sided and in another skull it was spotted bilaterally. The variation consisted of the branching of a 5 mm long canal from the lateral wall of the foramen rotundum that opened into the orbit. In general the diameter of the canal was comprised between 0.5 and 0.6 mm but it could be as large as 1 mm or as thin as 0.2 mm. The canal, straight and directed slightly superolaterally, likely transmitted the zygomatic nerve and/or part of the infraorbital nerve. To our knowledge, an independent entrance through a dedicated canal of such nerves has never been reported. The surgeons operating in this region, either neurosurgeons or ophthalmologists, should be aware of the possible variation in the course of these nerves.

### Key words

Foramen rotundum, infraorbital nerve, zygomatic nerve, sphenoid, orbit.

### Introduction

Several canals and openings, through which nerves and vessels enter and exit, connect the orbit with the cranial cavity. The infraorbital, ethmoidal, zygomatic and optic canals as well as the superior and inferior orbital fissures are constant and well-known. In addition, however, some minor canals can be inconstantly present: among them, we recall the meningo-orbital foramen (Diamond, 1991), the metoptic canal (Bertelli, 2013) and Warwick's foramen (Bertelli, 2013). Here, we report a previously unreported anatomic variation consisting of a canal connecting the orbit and the middle cranial fossa via the foramen rotundum.

### Materials and methods

We examined the collection of dried adult human skulls housed at the Anatomical Museum of the University of Siena, Department of Medicine, Surgery and Neu-

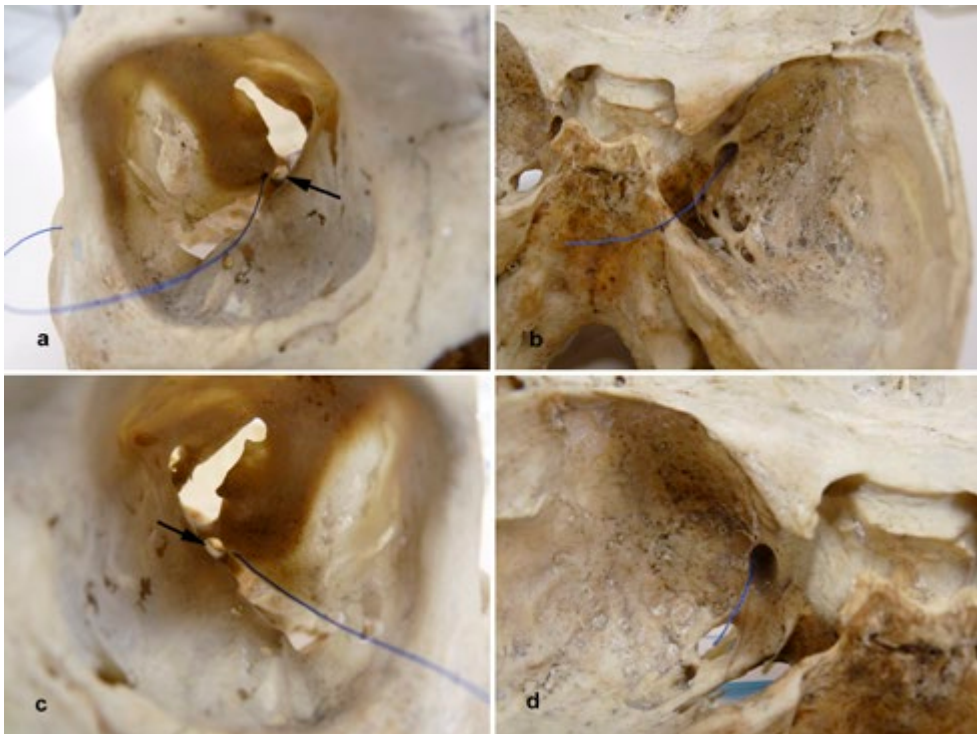
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rosiences. The collection, consisting of 943 adult skulls, was built over the years in a period comprised between 1880 and 1945.

The orbits of the skulls were examined to seek for anatomic variants of the foramen rotundum. As the variant that we were studying consisted of the branching of the foramen in a narrow canal, we always checked its patency with an appropriate probe. The calibre and length of the canal were also measured by the use of probes of known diameter.

## Results

We were examining the collection of dry skulls (943 skulls) housed at the Anatomical Museum of the University of Siena, Department of Medicine, Surgery and Neurosciences in order to investigate the incidence and general features of the metoptic canal and Warwick's foramen in human orbits (Bertelli, 2013), when we observed a previously unreported anatomic variation. The case was noted bilaterally in a skull



**Figure 1** – (A, B) Right orbit.,(C, D) left orbit, (A, C) orbital openings, (B, D) cranial openings of one skull. A surgical thread has been passed through the foramen rotundum and enters the orbit through an opening on the greater wing of the sphenoid. The foramen rotundum of both sides presented a single posterior opening in the middle cranial fossa and two anterior openings, one into the pterygopalatine fossa (arrows) and one into the orbit on the greater wing of the sphenoid (surgical thread).

of an individual of unknown sex and age. It consisted of a canal that branched from the lateral wall of the foramen rotundum and travelled anterosuperiorly straight through the greater wing of the sphenoid to open just above the inferior margin of the sphenoid orbital plate in proximity to the posterior end of the inferior orbital fissure (Fig. 1). The length and diameter of the canals were measured with probes of known caliber. The right canal was 1 mm in diameter whereas the left one was half that size. Both canals were approximately 5 mm long. A careful analysis of the entire collection of skulls allowed us to ascertain that this variation, though rare, was not unique. Indeed, we could observe a total of 11 cases. Only in one instance (the above mentioned one) the finding was bilateral. In nine other cases, the variation was right-sided and only in one case it was left-sided. The diameter of the secondary canal that branched from the foramen rotundum was almost constantly comprised between 0.5 and 0.6 mm. Only in two cases it was much smaller (0.2-0.3 mm) and in one case (the one showed here) it was far larger (1 mm). In three additional cases a similar canal opening in the orbital plate of the greater wing of the sphenoid did not originate from the foramen rotundum; in contrast its posterior opening was found in the pterygopalatine fossa. Thus, the incidence of a canal branching from the foramen rotundum could be estimated in 1.06% of skulls.

## Discussion

This anatomic variation was observed in a survey of almost 1000 skulls and was detected only in 10 individuals. It consisted of a secondary canal branching from the foramen rotundum and because of its low incidence and small caliber it has probably gone unnoticed up to now. Indeed, in spite of all our efforts, we have not been able to find any previous report describing such anomaly, not even in the long-lasting quoted Le Double's survey of variations of the human cranial bones (1903) or in Bergman's et al. (2013) illustrated encyclopedia of human anatomic variation. The only variation that somehow resembles our finding is the duplication of the foramen rotundum (Gruber, 1888, Rusu, 2011) that has been observed in 0.5% of cases (Gruber, 1888). The duplication observed by Rusu (2011) demonstrated that both foramina were occupied by part of the maxillary nerve. In particular, in Rusu's case the maxillary nerve originated from the trigeminal ganglion with two roots, each one running in a distinct foramen rotundum. Once reached the pterygopalatine fossa and the roots eventually joined to form the main nerve. For this reason, Rusu's anatomical variation was regarded as a case of fenestration of the maxillary nerve (Rusu, 2011). Gruber's report of duplication of the foramen rotundum in five skulls described bony canals that outlined a similar scenario (Gruber, 1888).

The anatomic variation that we observed differs from the previously reported duplication of the foramen rotundum in several respects: a) on the cranial side the foramen rotundum was single; b) the foramen rotundum had a single opening in the pterygopalatine fossa; c) a secondary canal branched from the foramen rotundum and opened into the orbit.

The content of the secondary canal can only be guessed. As the only important element that engages into the foramen rotundum is the maxillary nerve it is likely that the canal was occupied by the zygomatic nerve which is the only collateral

branch of the maxillary nerve entering the orbit. The observation that a similar canal originating from the pterygopalatine fossa can also exist supports this view. Alternatively, the canal might be occupied by fibers of the infraorbital nerve running forward with an anomalous course in the form of a long segmental duplication of the nerve. Indeed, the caliber of most of the observed canals is consistent with the passage of the zygomatic nerve. Only in one case (the one showed here on the right side) the caliber of the canal seems too large to host just the zygomatic nerve and might have housed other structures, either nervous (infraorbital nerve fibers) or vascular. Actually the foramen rotundum also accommodates a small artery, a branch of the inferolateral trunk of the internal carotid artery, referred to as the artery of the foramen rotundum (Lasjaunias et al., 1977). This small vessel is supposed to supply the maxillary nerve and to terminate in the foramen. Though far-fetched, we cannot completely rule out the possibility that in our case, for unknown reasons, this artery gained more importance reaching the orbit through the secondary canal and supplying some intraorbital structures.

The zygomatic nerve arises from the upper surface of the maxillary nerve in the pterygopalatine fossa but it can also originate when the maxillary nerve is still in the foramen rotundum (Testut and Latarjet, 1971). If during sphenoid chondrogenesis the foramen rotundum forms around the maxillary nerve it will likely result as a single foramen; in contrast, if it forms around either the maxillary or the zygomatic nerve it is possible that in exceptional cases the chondrogenetic process may find its way between the two nerves.

For its position, the canal can be interested by type III Le Fort fractures, depending on the precise course of the line of fracture, and by fractures of the lateral wall of the orbit. In any case, the outcome of an injury involving the nerve fibers passing through the canal is expected to result in sensory anesthesia of variable extensions of the cheek and/or temporal skin possibly combined with hypolacrimation due to postganglionic denervation of the lacrimal gland (Kawasaki, 2005). The canal and its content are also at risk when an extensive lateral approach is selected for surgical procedures of the orbital apex or to expose the cavernous sinus (Altay et al., 2012).

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The authors declare that they have no conflict on interest.

## References

- Altay T., Patel B.C.K., Couldwell W.T. (2012) Lateral orbital wall approach to the cavernous sinus. *J. Neurosurg.* 116: 755-763.
- Bergman R.A., Afifi A.K., Miyauchi R. (2013) Illustrated Encyclopedia of Human Anatomic Variation: Opus V: Skeletal Systems: Cranium. Sphenoid Bone. On line at: <http://www.anatomyatlases.org/AnatomicVariants/SkeletalSystem/Text/SphenoidBone.shtml>, accessed Dec 23, 2013.
- Bertelli E. (2014) Metoptic canal, duplication of the optic canal and Warwick's foramen in human orbits *Anat. Sci. Int.* 89: 34-45.

- Diamond M.K. (1991) Homologies of the meningo-orbital arteries of humans: a reappraisal. *J. Anat.* 178: 223-241.
- Gruber W. (1888) Über Duplicität des Foramen rotundum ossis sphenoides. *Arch. Pathol. Anat. Physiol. Klin. Med.* 113: 533.
- Kawasaki A. (2005) Disorders of pupillary function, accommodation, and lacrimation. In: Miller N.R., Newman N.J., Bioussé V., Kerrison J.B. (Eds.) *Walsh and Hoyt's Clinical Neuroophthalmology*, Vol. I. 6th edn. Philadelphia, Lippincott Williams & Wilkins. Pp. 739-808.
- Lasjaunias P., Moret J., Mink J. (1977) The anatomy of the inferolateral trunk (ILT) of the internal carotid artery. *Neuroradiology* 13: 215-220.
- Le Double A.F. (1903) *Traité des Variations des Os du Crane de l'Homme*. Paris, Vigot Frères.
- Rusu M.G. (2011) Doubled foramen rotundum and maxillary nerve fenestration. *Surg. Radiol. Anat.* 33: 723-726.
- Testut L., Latarjet A. (1971) *Traité d'Anatomie Humaine*. Paris, Doin G & C.ie.