Published in final edited form as:

J Craniofac Surg. 2016 June ; 27(4): 1094–1097. doi:10.1097/SCS.0000000000002619.

Anatomical Study of the Intraosseous Pathway of the Infraorbital Nerve

Dennis C. Nguyen, MD, Scott J. Farber, MD, Grace T. Um, MD, Gary B. Skolnick, BA, Albert S. Woo, MD, and Patel Patel, MD

Division of Plastic and Reconstructive Surgery, Department of Surgery, Washington University, St. Louis, MO, USA

Abstract

BACKGROUND—The infraorbital nerve (ION) is at risk for iatrogenic injury during orbital floor repair. We aim to anatomically characterize the intraosseous course of the ION between the inferior orbital fissure and infraorbital foramen.

METHODS—Ten cadaver heads (twenty orbits) were dissected, with exposure of the orbital floor. The ION was identified from the infraorbital fissure to inferior orbital foramen. The presence and caliber of an osseous roof was noted. Distances measured were (1) infraorbital foramen to infraorbital margin; (2) length of the inferior orbital groove; (3) length of the inferior orbital canal; (4) length from the inferior orbital fissure to the infraorbital margin.

RESULTS—Three variations of the osseous anatomy around the ION were identified. Four cadavers had no identifiable groove (Type 1, 40%) and the ION was completely roofed throughout its course. Five specimens exhibited a thin, transparent osseous roof over the nerve before forming the true canal, which we describe as a “pseudocanal” (Type 2, 50%). A true groove was seen in both orbits from a single cadaver (Type 3, 10%). Each cadaver had an ION course of the same type on both sides. Mean±S.D. intraorbital foramen to infraorbital margin distance was 7.1±1.4 mm. Distance from the infraorbital fissure to the infraorbital margin was 28.5±2.3 mm.

CONCLUSIONS—The course of the infraorbital nerve can be described as Type 1 (true canal), Type 2 (pseudocanal) and Type 3 (groove and canal). The authors propose that this novel classification system will raise awareness of variations in orbital floor anatomy.

INTRODUCTION

The infraorbital nerve (ION) is a terminal sensory branch of the maxillary nerve. The fibers originate from the semilunar ganglion and traverse the cavernous sinus and foramen rotundum before entering the orbit via the infraorbital fissure (1). The ION travels anteriorly in the floor of the orbit through the infraorbital canal and exits from the infraorbital foramen of the maxillary bone. Within the infraorbital canal, the ION branches into the anterior-

Corresponding Author: Dennis C. Nguyen, MD, Washington University in Saint Louis, Plastic and Reconstructive Surgery, 660 South Euclid Avenue, Campus Box 8238, St. Louis, MO 63110, Office: (314) 747-1193, Fax: (314) 367-0225.

Financial Disclosures: Dr. Patel is a consultant for Stryker CMF. Dr. Woo is a consultant for Osteomed.

The other authors have no conflicts of interest to report.

superior and middle alveolar nerves, which innervate the canine and incisor teeth, and premolar and first molar teeth, respectively (2). Ultimately, the nerve is flanked by the levator labii superioris and levator anguli oris prior to reaching the skin. The palpebral, nasal, and labial branches provide sensation to the skin of the conjunctiva, lower eyelid, lateral external nose and upper lip. Detailed knowledge of this nerve and its branches is essential for success during periorbital procedures or regional anesthesia.

The orbital floor provides support for the globe and forms the roof of the maxillary sinus. The term “blow-out” fracture is often used whenever the orbital floor is involved and is found in up to 47 percent of all orbital injuries (3). The ION and its associated blood vessels are often at risk for iatrogenic injury during osteotomies or reconstruction of the orbital floor. The aim of this study is to anatomically characterize the intraosseous course of the ION between the inferior orbital fissure and infraorbital foramen.

METHODS

Dissections of the infraorbital region of ten fresh adult cadaver head specimens were performed, producing twenty samples for analysis. The infraorbital foramen and orbital floors were carefully exposed on both sides of each of the head specimens. The ION was dissected out from the foramen to the inferior orbital fissure.

Two observers obtained six measurements from each specimen (three from each side). The measurements included length of the infraorbital groove (if present), length from the infraorbital margin to the point where the infraorbital nerve enters the canal, and finally distance from the foramen to the margin (Figure 1A).

Statistical Analysis

Interrater reliability for all measures was determined using coefficients of variation and intraclass correlation coefficients (two-way random effects average measures). Unpaired t-tests and ANOVA were used to compare means between orbit types. Fisher’s exact test was used to compare proportions of orbit types between genders. SPSS V.22 (Chicago, IL) was for statistical analyses and values of $p < 0.05$ were considered significant.

RESULTS

The age range of the 10 heads was between 79 and 97 years of age (mean $\pm$ standard deviation: 84.4 ± 5.5 years). Four of the specimens were male and six were female.

Three variations of orbital floor osseous anatomy were found in these specimens and are described as follows. In the first type, there is no groove and the nerve enters the canal covered by true roof. In the second type, there is a “pseudocanal” with a very thin, almost transparent roof. Finally, the third type consists of the nerve traveling in a true groove first before entering a canal. Of the twenty orbits that were dissected, four cadavers had no identifiable groove (Type 1, 40%, Figure 1B). Five specimens (10 orbits) were noted to have a pseudocanal, (Type 2, 50%, Figure 1C). A true groove in conjunction with a canal were

seen in both orbits from the same cadaver (Type 3, 10%, Figure 1D). Each cadaver had an ION course of the same type on both sides.

Mean distance $\pm$ standard deviation from the inferior orbital fissure to the infraorbital margin for all measured orbits was 28.5 ± 2.3 mm. There was no significant differences for this measurement when analyzed by laterality or type ($0.486 < p < 0.637$, Table 1). Fissure to margin was equivalent between males (28.8 ± 1.3 mm) and females (28.3 ± 2.8 mm) ($p=0.644$). Length of canal in all orbits was 15.8 ± 10.4 and there was no difference between the right and left orbits ($p=0.984$). Type 1 orbits exhibited the longest canal length (27.8 ± 1.8 mm), followed by Type 3, and Type 2 ($p<0.001$; Table 2). The canal length in male specimens (23.5 ± 9.4 mm) were significantly longer than those in female specimens (10.6 ± 7.6 mm) ($p=0.003$). When present, the groove length of the orbits measured 21.3 ± 2.8 mm. While a groove does not exist in a Type 1 orbit, groove length was equivalent between Type 2 and Type 3 orbits (Table 3). Lastly, the average distance from the infraorbital margin to infraorbital foramen was 7.1 ± 1.4 mm for all specimens. No significant differences were found when analyzed by either laterality or type ($0.166 > p > 0.253$, Table 4). Margin to foramen distances were the same between males (6.6 ± 0.9 mm) and females (7.3 ± 1.7 mm) ($p=0.290$).

DISCUSSION

The infraorbital groove and canal create a natural passage for the ION and vessels as they travel from the fissure to foramen. Scarfe et al. first described and classified the presentations of what they termed the “infra-orbital canal/groove complex” (4). In their study of 246 panoramic radiographs, the authors identified three different variants: canal only (42%), groove only (13.2%) and a combined canal and groove (44.8%). Their study established the basis for several other subsequent classification schemes based on either dry skulls or computed tomography scans (5–8). Injury to the nerve within the canal/groove complex will result in paraesthesia. Our proposed classification system (Type 1: canal only; Type 2: pseudocanal; Type 3: canal and groove), based on cadaver dissections, is aimed at increasing awareness of possible variants in the bony structures of the orbital floor and reduce potential neurovascular injury. The study by Scarfe et al. did not describe patterns resembling our “Type 2” orbit. We believe that a pseudocanal may not be well characterized on plain film images, considering that the canal/groove complex cannot be visualized in 1 in 5 radiographs (4). The clinical significance of the Type 2 and 3 orbit is that the nerve can be more easily and inadvertently injured during exploration of the floor.

In a study of dry Korean skulls, Lee et al. proposed an alternative classification of the infraorbital canal based on its 3-dimensional morphology (9). Using V-works software (Cybermed, Korea), the authors showed that the canal takes on one of three shapes as it inserts into the infraorbital foramen: tubular (69%), funnel (25%), and pinched (6%). The mean angle of the canal relative to the Frankfort horizontal was 44° in all three described morphologies. While the classification by Lee et al. may be useful during needle positioning for infiltrating local anesthesia, our classification of the canal may help reduce the risk of injuring the ION during procedures of the orbital floor. Using their 3-D imaging technology, Lee et al. was able to meticulously describe the shape and trajectory of the infraorbital canal;

however, the thickness of the bone overlying the nerve would also be clinically useful. Our study objectively describes the floor and awareness of orbital floor type is important when considering implant placement. Titanium implants and porous polyethylene implants (Medpor® / Medpor Titan®, Stryker, MI) are frequently used in reconstruction of orbital floor fractures (10). Medpor implants are available with a single or double-sided protective layer (Barrier™) to prevent tissue ingrowth, which is particularly important on the globe surface. In our experience, tissue ingrowth and scarring on the orbital floor-side of the implant make it difficult when implant removal is desired, increasing the risk of ION injury. Implants with barrier on both the globe surface and posterior aspect of the orbital-side may potentially reduce unwanted adhesions.

Several mechanisms of ION injury have been described in the literature. The ION and its associated vessels are rarely injured by direct trauma, but it may indirectly be affected by compression from nearby fractures (i.e., malar fractures) (6). Several studies have shown that the orbital floor is relatively thin medial to the ION and can be easily fractured in this region (6, 11–14). Additionally, it has been suggested that orbital floors containing a groove are mechanically weaker and are more prone to fractures (7). Similarly, iatrogenic injury of the ION is rare and has been reported in surgical procedures such as rhinoplasty, tumor excision, reduction of orbital fractures and Le Fort I (2, 15, 16). Difficulty can arise in identifying and protecting this nerve during subperiosteal dissection of orbital floor. This may be, in part, due to either the surgeon's inability to adequately expose the floor or faulty assumption that the nerve is well protected in its entire length from direct injuries. Our recommendation for subperiosteal dissection of the orbital floor follows the surgical adage of "known-to-unknown." We begin at the most distal extent, along the orbital rim. Our findings showed that the ION is most protected by bone in this region. Incision through the periosteum below the arcus marginalis and dissection should also commence along the lateral aspect of the rim and proceed posterior and medial. The bone stock is thicker laterally and there is less risk of fracture and entry into the maxillary sinus. Furthermore, we are able to stay away from the inferior oblique, which arises adjacent to the nasolacrimal canal. Upon exiting the fissure, the nerve may be completely exposed in a groove (Type 3) or partially protected only by a thin a transparent "pseudocanal" (Type 2).

In another interesting classification scheme, Przygocka et al. divided the infraorbital complex/groove into thirds and found that groove is longer than 1/3 and shorter than 2/3 of the IOC/G in 68.6% of cases (7). This suggests that the most common variation of the orbital floor will have 33.3–66.6% of the nerve exposed. The measurements were taken from dry skulls of indeterminate ages and thus, the results are challenging to generalize. Our study shows that the groove, similarly found in 60% of orbits, is approximately 21 mm in length. Clinically, the findings of this study and that of Przygocka demonstrate that the infraorbital nerve is unprotected a majority of the time and that one should be aware of the nerve within 2 cm of the fissure.

There is a wide range of values in the surgical literature regarding the dimensions of the ION, the canal and the location of the infraorbital foramen. The variability that exists is likely due to the use of different landmarks (e.g., location along margin, edge of foramen versus center of foramen, etc.). To the best of our knowledge, this is the first fresh cadaver

study describing the variable bony structure surrounding the ION as it traverses the orbital floor. In our sample of cadavers, the canal length was the measurement with greatest variability. Type 1 orbital floors (canal only) were the longest, followed by Type 3 (canal and groove) and Type 2 (pseudocanal) (Table 2). On average, the true canal portion was 40% in Type 3 orbits, whereas it made up 25% of Type 2 orbits. A potential confounder, though not statistically significant, is that Type 1 orbits were found predominantly in male cadavers, while Type 2 orbits were found predominantly in female cadavers (p -value = 0.190). The thin and transparent portion of the “pseudocanal” found in Type 2 orbits may represent more osteoporotic bone stock in elderly females as compared to males (17). Additional studies in orbital floor morphology as it relates to injury susceptibility, especially in the elderly, are needed.

The infraorbital foramen is the exit site for the ION and its anatomy relative to other facial structures has been well described. Distal to the infraorbital foramen the ION is responsible for the sensory innervation to that part of the face between the lower eyelid and the upper lip (1). In a study of 45 skulls by Hindy et al., the authors reported that the foramen is situated opposite the 2nd maxillary premolar a majority of the time (5). The canal length (28.8 mm) and distance from margin to infraorbital foramen (6.1 mm) measured by the authors were similar to our own numbers. As an alternative measurement, the horizontal distance of the foramen from the zygomatico-maxillary suture is 11 mm (18). The infraorbital foramen is an important anatomic landmark from both a surgical and local anesthetic perspective. With this information, local anesthesia can be effectively injected between 6 to 8 mm below the infraorbital margin along the same vertical plane as the 2nd maxillary premolar with the intent of avoiding direct injection into the nerve (18, 19). Of note, we did not attempt to identify accessory foramina in this study. Although a single foramen is the most frequently identified pattern (20), several studies reported the incidence of double and triple foramina to be between 2.2–18.2% and 0.5–1.28%, respectively (1, 19, 21). Canan et al. found that accessory foramen are found superior and medial to the main foramen in 79.6% of specimen (21). These variants of the infraorbital foramen are worth noting during local anesthetic planning.

Several limitations exist in our study. Notably, the dissections and measurements were performed on elderly cadavers without any history of orbital trauma. The shape, size, and volume of the periorbital bones have all been shown to change with age. In anatomical studies on the effects of aging on the craniofacial skeleton, there was posterior-superior movement of the skeleton orbit and anterior-inferior displacement of the skeleton superior to the orbit (22, 23). The process of bony resorption and volume loss in the elderly midface may account for differences in our findings compared to other studies. Although we were unable study the orbital floor in younger skulls, it is known that facial skeleton remodels throughout adulthood. Based on prior radiologic investigations, orbits of younger patients (e.g., 25–45 years old) have narrower orbital widths and greater bone density (22, 24). We speculate that the proportion Type 2 is lower with a compensatory increase in Type 1 orbits in the younger population, since the pseudocanal roof will be more robust. In a patient with an acute or recent orbital trauma, the structures and relationships may be difficult to appreciate due to swelling, bone fragments and possible scarring. The limited number of dissected orbits, tissue quality, exposure and size differences may preclude extrapolation of

our findings to all orbits. Nonetheless, this study provides a novel classification of the ION course from the fissure to the foramen. Lastly, without preoperative imaging, it can be challenging to determine the orbital floor type until after the operation has already begun. Potential future studies include investigating ION type in patients with orbital fractures based on CT imaging and determining whether ION type has any effect on fracture risk.

CONCLUSIONS

A detailed knowledge of the anatomic morphometry of bony structures surrounding the ION is necessary for a surgeon while performing regional anesthesia and procedures involving the orbital floor. Anatomical variations of the orbital floor should be taken into consideration to avoid iatrogenic injury of the ION. Risk of nerve injury is increased when dissecting over a pseudocanal (Type 2) or groove (Type 3) orbit.

Acknowledgments

Research reported in this publication was supported by the Washington University Institute of Clinical and Translational Sciences grant UL1 TR000448 from the National Center for Advancing Translational Sciences (NCATS) of the National Institutes of Health (NIH) and the Children's Discovery Institute. The content is solely the responsibility of the authors and does not necessarily represent the official view of the NIH.

REFERENCES

1. Leo JT, Cassell MD, Bergman RA. Variation in human infraorbital nerve, canal and foramen. *Annals of anatomy = Anatomischer Anzeiger : official organ of the Anatomische Gesellschaft.* 1995; 177:93–95. [PubMed: 7872502]
2. Kazkayasi M, Ergin A, Ersoy M, Tekdemir I, Elhan A. Microscopic anatomy of the infraorbital canal, nerve, and foramen. *Otolaryngology--head and neck surgery : official journal of American Academy of Otolaryngology-Head and Neck Surgery.* 2003; 129:692–697. [PubMed: 14663437]
3. Hwang K, You SH, Sohn IA. Analysis of orbital bone fractures: a 12-year study of 391 patients. *The Journal of craniofacial surgery.* 2009; 20:1218–1223. [PubMed: 19553835]
4. Scarfe WC, Langlais RP, Ohba T, Kawamata A, Maselle I. Panoramic radiographic patterns of the infraorbital canal and anterior superior dental plexus. *Dento maxillo facial radiology.* 1998; 27:85–92. [PubMed: 9656872]
5. Hindy AM, Abdel-Raouf F. A study of infraorbital foramen, canal and nerve in adult Egyptians. *Egyptian dental journal.* 1993; 39:573–580. [PubMed: 9588126]
6. Kazkayasi M, Ergin A, Ersoy M, Bengi O, Tekdemir I, Elhan A. Certain anatomical relations and the precise morphometry of the infraorbital foramen--canal and groove: an anatomical and cephalometric study. *The Laryngoscope.* 2001; 111:609–614. [PubMed: 11359128]
7. Przygocka A, Szymanski J, Jakubczyk E, Jedrzejewski K, Topol M, Polguy M. Variations in the topography of the infraorbital canal/groove complex: a proposal for classification and its potential usefulness in orbital floor surgery. *Folia morphologica.* 2013; 72:311–317. [PubMed: 24402752]
8. Yenigun A, Gun C, Uysal II, Nayman A. Radiological classification of the infraorbital canal and correlation with variants of neighboring structures. *European archives of oto-rhino-laryngology : official journal of the European Federation of Oto-Rhino-Laryngological Societies (EUFOS) : affiliated with the German Society for Oto-Rhino-Laryngology - Head and Neck Surgery.* 2015
9. Lee UY, Nam SH, Han SH, Choi KN, Kim TJ. Morphological characteristics of the infraorbital foramen and infraorbital canal using three-dimensional models. *Surgical and radiologic anatomy : SRA.* 2006; 28:115–120. [PubMed: 16432643]
10. Gart MS, Gosain AK. Evidence-based medicine: Orbital floor fractures. *Plastic and reconstructive surgery.* 2014; 134:1345–1355. [PubMed: 25415098]

11. Bansagi ZC, Meyer DR. Internal orbital fractures in the pediatric age group: characterization and management. *Ophthalmology*. 2000; 107:829–836. [PubMed: 10811070]
12. Chien HF, Wu CH, Wen CY, Shieh JY. Cadaveric study of blood supply to the lower intraorbital fat: etiologic relevance to the complication of anaerobic cellulitis in orbital floor fracture. *Journal of the Formosan Medical Association = Taiwan yi zhi*. 2001; 100:192–197. [PubMed: 11393115]
13. Przygocka A, Podgorski M, Jedrzejewski K, Topol M, Polguj M. The location of the infraorbital foramen in human skulls, to be used as new anthropometric landmarks as a useful method for maxillofacial surgery. *Folia morphologica*. 2012; 71:198–204. [PubMed: 22936558]
14. Rene C. Update on orbital anatomy. *Eye*. 2006; 20:1119–1129. [PubMed: 17019410]
15. Lawrence JE, Poole MD. Mid-facial sensation following craniofacial surgery. *British journal of plastic surgery*. 1992; 45:519–522. [PubMed: 1446195]
16. Meyer M, Moss AL, Cullen KW. Infraorbital nerve palsy after rhinoplasty. *Journal of cranio-maxillo-facial surgery : official publication of the European Association for Cranio-Maxillo-Facial Surgery*. 1990; 18:173–174. [PubMed: 2358507]
17. Seeman E. Pathogenesis of bone fragility in women and men. *Lancet*. 2002; 359:1841–1850. [PubMed: 12044392]
18. Gupta T. Localization of important facial foramina encountered in maxillo-facial surgery. *Clinical anatomy*. 2008; 21:633–640. [PubMed: 18773483]
19. Aziz SR, Marchena JM, Puran A. Anatomic characteristics of the infraorbital foramen: a cadaver study. *Journal of oral and maxillofacial surgery : official journal of the American Association of Oral and Maxillofacial Surgeons*. 2000; 58:992–996.
20. Agthong S, Huanmanop T, Chentanez V. Anatomical variations of the supraorbital, infraorbital, and mental foramina related to gender and side. *Journal of oral and maxillofacial surgery : official journal of the American Association of Oral and Maxillofacial Surgeons*. 2005; 63:800–804.
21. Canan S, Asim OM, Okan B, Ozek C, Alper M. Anatomic variations of the infraorbital foramen. *Annals of plastic surgery*. 1999; 43:613–617. [PubMed: 10597821]
22. Kahn DM, Shaw RB Jr. Aging of the bony orbit: a three-dimensional computed tomographic study. *Aesthetic surgery journal/the American Society for Aesthetic Plastic surgery*. 2008; 28:258–264. [PubMed: 19083535]
23. Richard MJ, Morris C, Deen BF, Gray L, Woodward JA. Analysis of the anatomic changes of the aging facial skeleton using computer-assisted tomography. *Ophthalmic plastic and reconstructive surgery*. 2009; 25:382–386. [PubMed: 19966653]
24. Sirichai P, Anderson PJ. Orbital fractures in children: 10 years' experience from a tertiary centre. *The British journal of oral & maxillofacial surgery*. 2015

Figure 1.

A) An example of measurements taken in a left Type 3 orbit. The measurements included length of the infraorbital groove (dotted line), length from the infraorbital margin to the point where the infraorbital nerve enters the canal (green solid line), and finally distance from the foramen to the margin (red solid line). B) Left orbit Type 1 – ION lies completely within the canal. There is no groove. Instrument tip inserted into inferior orbital fissure. C) Right orbit Type 2 – ION lies within a “pseudocanal” The roof, indicated by the arrow, is thin and transparent. Bottom: A separate specimen with an instrument tip inserted into the inferior orbital fissure. The canal is easily unroofed and the infraorbital margin is opened. The ION is exposed from the infraorbital fissure to the infraorbital foramen. D) Left orbit

Type 3 – ION lies within a true groove before entering the canal. Instrument tip inserted into inferior orbital fissure.

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Table 1

Length from inferior orbital fissure to infraorbital margin (millimeters).

	All orbits	Right-side only	Left-side only	All Type 1	All Type 2	All Type 3
N	20	10	10	8	10	2
Mean	28.5	28.2	28.7	27.8	29.1	28.0
SD	2.3	1.9	2.7	1.8	2.7	1.4
p-value	0.637			0.486		

Table 2

Length of canal (millimeters).

	All orbits	Right-side only	Left-side only	All Type 1	All Type 2	All Type 3
N	20	10	10	8	10	2
Mean	15.8	15.8	15.7	27.8	7.0	11.5
SD	10.4	10.8	10.5	1.8	2.9	0.7
p-value	0.984			<0.001		

Table 3

Length of groove (Type 2 & 3), when it exists (millimeters).

	All orbits	Right-side only	Left-side only	All Type 1	All Type 2	All Type 3
N	12	6	6	---	10	2
Mean	21.3	21.3	21.3	---	22.0	18
SD	2.8	3.0	2.8	---	2.5	0
p-value	0.999			0.057		

Table 4

Length from infraorbital margin to infraorbital foramen (millimeters).

	All orbits	Right-side only	Left-side only	All Type 1	All Type 2	All Type 3
N	20	10	10	8	10	2
Mean	7.1	6.6	7.5	7.4	7.1	5.5
SD	1.4	1.2	1.6	1.9	0.9	0.7
p-value	0.166			0.253		