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Morphometric Analysis of the Supraorbital Foramen in the South African Population

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ABSTRACT

Introduction

The supraorbital notch (SON) or supraorbital foramen (SOF) houses the supraorbital neurovascular bundle which supplies the scalp, skin and muscles of the upper eyelid. Surgeons operating in the region may be cautious about performing surgical procedures in this region due to the increased risk of injury.

Aim

To assess the morphological characteristics of the supraorbital foramen in the South African population

Methods

108 dry skulls were examined, to determine the following morphometric data: width of SON/SOF and position of SON/SOF relative to the nasal midline and frontozygomatic suture. Left and right sides were compared and differences between the sexes was considered.

Results

The SON (44%) was the most commonly identified passageway, followed by the SOF (27%), absent SON/SOF (19%), double foramen (5%), co-occurrence (4%), and double notch (1%) respectively. This study localised the SON/SOF approximately 26.87 mm ± 4.21 from the nasal midline to SON/SOF in females, and 28.20 mm ± 3.68 in males. When using the frontozygomatic suture as a reference point, SON/SOF lies 28.42 mm ± 3.00 medially in females and 29.83 mm ± 2.80 in males. Positional distances were significantly greater in males than females. No significant differences were observed between the left and right sides. The width of SON was approximately 4.16 mm ± 1.81, and the diameter of SOF was approximately 2.60 mm ± 1.14.

Conclusion

Accurate anatomical knowledge of the neurovascular architecture and foramina localisation can help avoid iatrogenic injury.

Keywords

Anatomy, Morphology, South Africa, Supraorbital notch, Supraorbital foramen.

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Authors' Contributions:

1. K Ramkissoon – study design, data collection, data analysis, data interpretation and drafting of the manuscript
2. A Bhika, MA Bobat, RE Rikhotso – study conception & supervision of the entire work

INTRODUCTION

The supraorbital foramen (SOF) is an elongated bony aperture above the orbit and below the forehead. When the passage is encircled by bone, it is referred to as the supraorbital foramen, however, when partly enclosed in bone, it is called the supraorbital notch (SON)[1]. The supraorbital foramen or supraorbital notch is located along the supraorbital margin on the frontal bone[2]. The terminal point houses the supraorbital nerve, artery and vein. This nerve forms the largest branch of the frontal nerve, extending from the ophthalmic division of the trigeminal nerve (Cranial Nerve V). The supraorbital nerve is bounded by the orbital roof and levator palpebrae muscle[3]. The nerve subdivides into two branches: a medial (superficial) branch which journeys through the frontal foramen or notch, providing sensation to the medial part of the upper eyelid, medial forehead, and bridge of the nose; and a thicker lateral (deep) branch which usually exits through the SON/SOF providing sensory innervation to the skin of the forehead (extending from the parietal to the temporal regions[4]. The supraorbital artery forms a branch of the ophthalmic artery, originating from the internal carotid artery. After passing through SON/SOF, it separates into the superficial and deep branches that supply muscles and skin of the forehead, scalp and upper eyelid. The supraorbital vein joins the supratrochlear vein at the medial angle of the eye to form the angular vein which continues through the face as the facial vein[5].

Comprehensive knowledge of the regional anatomy of the supraorbital nerve, vessels, and exit passageway is crucial in combination with modern diagnostic and therapeutic methods and surgical procedures in the supraorbital region[4]. This includes procedures such as corneal neurotization, anterior orbital approach, supraorbital injections, treatment of migraine headaches, fronto-glabellar reconstruction flap, upper eyelid surgeries (e.g., blepharoplasty), and any

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procedure requiring incisions in the forehead endoscopic facial therapies[4].

Surgeons operating in the region may be cautious to perform surgical procedures in this region due to the increased risk of injury to the supraorbital nerve and causing loss of sensation[2]. Effective and precise analgesia can only be achieved with a thorough understanding of the position of the nerve and its point of exit. Excessive retraction and dissection near the neurovascular bundle can result in scarring, leading to painful neuralgias. Clinicians need to be cognizant of the anatomical position and dimensions of the SON/SOF when diagnosing and treating conditions in the region, such as supraorbital neuralgia[2].

Previous studies have indicated variation in the location and morphology of the SON/SOF amongst different population groups such as Nigerians, Sri Lankans, Koreans, Caucasians, and South Indians[1,2,4,5,6]. In addition, these characteristics may differ between populations and within inhabitants of the same geographical location[6]. No studies have been conducted in the South African population. Understanding the specific morphometric traits of the South African population can provide data that accurately reflects the unique characteristics of this group, leading to more precise clinical assessments and interventions.

AIM AND OBJECTIVES

Aim

To assess the morphological characteristics of the supraorbital foramen in the South African population.

Objectives

1. To determine the existence of various morphologies of the supraorbital notch/foramen across the population and sexes of interest.
2. To determine the width of the supraorbital notch and/or diameter of the supraorbital foramen on human skulls.
3. To determine the distance from the nasal midpoint to the midpoint of the supraorbital notch or foramen.
4. To determine the distance from the midpoint of the supraorbital notch/foramen to the frontozygomatic point.

MATERIALS AND METHOD

The study population included 108 dry skulls from The Raymond A. Dart Collection of Modern Cadaveric Human Skeletons of the School of Anatomical Sciences at the University of the Witwatersrand[7]. In this study, the dry skull was defined as a skull including cranial bones & facial bones, without the mandible and calvaria. Only specimens of known population affinity, age and sex were included.

The crania of the study were used in compliance with the South African National Health Act 61 of 2004. An ethics clearance waiver issued to the School of Anatomical Sciences, University of the Witwatersrand was obtained W-CBP-220504-01. The age, population affinity and sex of the skulls were recorded. The study included 54 male and 54 female skulls. The age of the crania ranged from 20 years to 90 years, with a median age of 50 years old.The required sample size was calculated and required 104 macerated skulls.

Measurements

Digital vernier calipers (Guanglu ISO9001:2000 (China) were used to conduct the relevant osteometric measurements (Figure 1):

- Demographic data including: age, sex, and population affinity was captured.
- Width of the SON or diameter of SOF.
- Distance from the frontozygomatic point to the midpoint of the SON/SOF.
- Distance from the midpoint of the SON/SOF to the nasal midline.

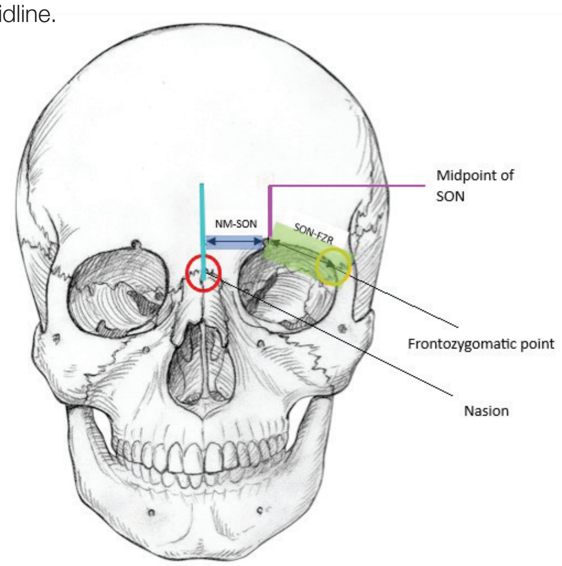

Figure 1: Osteometric measurements. NM-SON: Nasal Midline-Supraorbital Notch; SON-FZR: Supraorbital notch-Frontozygomatic point. Adapted from Ashwini *et al*[5]

Table 1

Landmark/Measurement	Abbreviation	Description
Nasion	n	A bony depression at the midpoint where the two nasal bones and the frontal bone intersect.
Frontozygomatic point	FZR	The most medial and anterior point of the frontozygomatic suture in the plane of the lateral orbital rim.
Nasal midline	NM	
Straight line from the nasion extending superiorly		
Nasal midline-supraorbital notch	NM-SON	Straight line measurement from the nasal midline to the midpoint of the supraorbital notch.
Supraorbital notch-frontozygomatic point	SON-FZR	Straight line measurement from the midpoint of the supraorbital notch to the most medial and anterior point of the frontozygomatic suture.
Midpoint of supraorbital notch		Determined as half the width of the supraorbital notch

The researcher (1st observer) measured the entire sample population. Measurements were repeated in triplicate and the mean was recorded (intra-observer reliability). A second observer (supervisor) conducted independent measurements on one-third of the sample (interobserver measurements) using the same calipers and method as the 1st observer. A single set of instruments was used to ensure reliability. Intraclass Correlation Coefficient (ICC) was used to quantify the agreement between observers' measurements (interobserver reliability).

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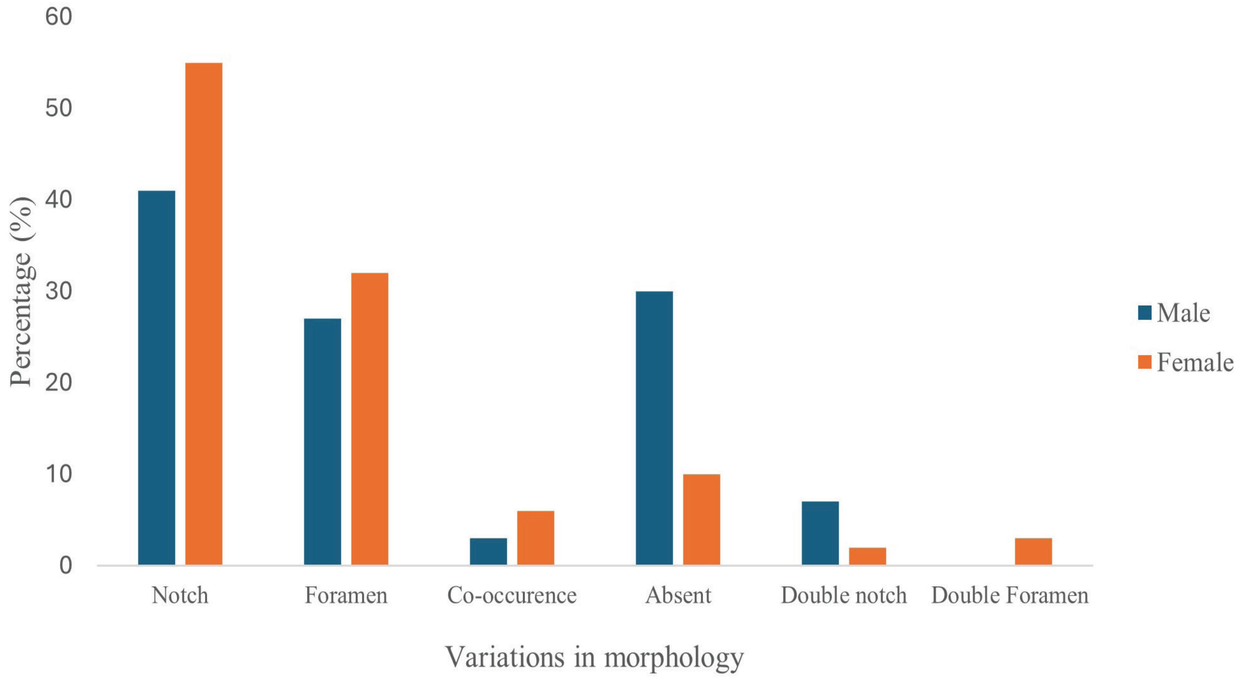

Figure 2: Frequency distribution amongst sexes in the South African population.

Data analysis:

Data was captured on Microsoft Excel 2021 (Microsoft Corporation). Data was then exported to Statistical Package for Social Service (SPSS) (Version 28). Descriptive statistics of the data was utilised to determine the minimum, maximum, mean and standard deviation of the groups under analysis. Thereafter, a Shapiro-Wilk test was used to test for the normality distribution of the data. A t-test was used to analyse differences observed in the measurements between the right and left sides of the skull and the differences observed between sexes where the data was normally distributed.

A Mann-Whitney U test was used if data was non-parametric. The significance level was set at $p \leq 0.05$.

RESULTS

The study population consisted of 108 specimens, 54 males and 54 females. The age of the crania ranged from 20 years to 90 years, with a median age of 50 years old.

The reliabilities for each measurement were above 0.8, indicating good reliability.

Different morphologies including the supraorbital notch (SON), supraorbital foramen (SOF), absent SON/SOF, double foramen, co-occurrence, and double notch were identified in our sample population (Figure 2). When comparing the frequency in the distribution of morphologies in a South African population SON (44%) was the most commonly identified passageway, followed by the SOF (27%), absent SON/SOF (19%), double foramen (5%), co-occurrence (4%), and double notch (1%) respectively (Figure 3).

Figure 3 (a): image depicts SON

Figure 3(b): image depicts absent SON/SOF

Figure 3(c): Image depicts SOF

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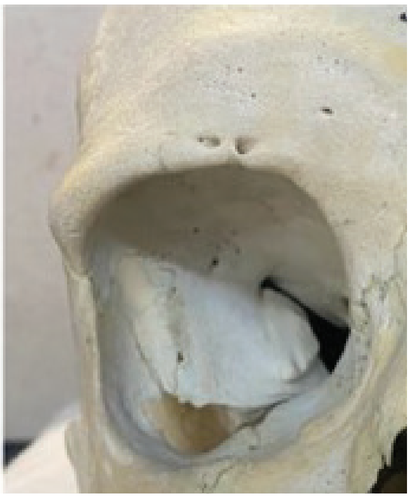

Figure 3(d): Image depicts double foramen

Figure 3(e): Image depicts cooccurrence

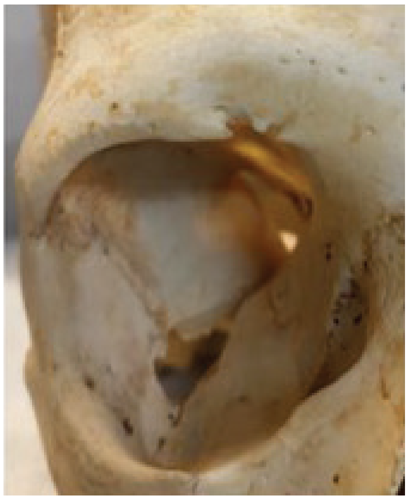

Figure 3(f): Image depicts double notch

Figure 3: Images depict the different morphologies seen: (a) supraorbital notch (SON), (b) absent SON/SOF; (c) SOF; (d) double foramen; (e) co-occurrence; (f) double notch

This study determined the dimensions of SON/SOF in South African females and males; and compared the left and right sides and differences between sexes. No significant differences in dimensions between left and right sides in males and females was exhibited (Tables 1-4).

TABLE II: POSITION OF SON/SOF IN FEMALES

	Width of SON/ Diameter of SOF (mm)	
	Right side	Left side
Min	1.10	0.71
Max	9.80	8.25
Mean	3.88	3.40
Median	3.35	3.04
Standard deviation	2.19	1.49
P-value	0.46	

TABLE III: POSITION OF SON/SOF IN FEMALES

	Distance to nasal midline (NM-SOF) (NM-SON) (mm)		Distance to (SOF-FZR) (SON-FZR) (mm)	
	Right side	Left side	Right side	Left side
Min	17.96	18.26	21.87	21.79
Max	34.83	40.52	35.67	35.02
Mean	26.53	27.18	28.72	29.01
Median	26.48	27.02	28.10	28.09
Standard deviation	3.74	4.11	2.72	3.24
P-value	0.10	0.28		

TABLE IV: WIDTH OF SON/SOF SEEN IN MALES

Width of SON/ Diameter of SOF (mm)		
	Right side	Left side
Min	0.69	0.97
Max	9.60	6.31
Mean	3.47	3.36
Median	3.39	3.19
Standard deviation	1.74	1.50
P-value	0.78	

TABLE V: POSITION OF SON/SOF IN MALES

	Distance to nasal midline (NM-SOF) (NM-SON) (mm)		Distance to frontozygomatic point (SOF-FZR) (SON-FZR) (mm)	
	Right side	Left side	Right side	Left side
Min	17.30	20.13	23.08	23.97
Max	35.67	33.84	35.23	40.36
Median	28.62	28.29	29.58	29.81
Standard deviation	4.07	3.24	2.55	3.04
P-value	0.63	0.58		

In this study, dimensions and relative position of SON/SOF were compared between South African males and females.

In reference to dimensions, statistical analysis revealed no significant differences between males and females ($p = 0.46$).

TABLE VI: WIDTH OF SON/SOF SEEN IN THE FEMALE & MALE SAMPLE

	Width of SON/ Diameter of SOF (mm)	
	Females	Males
Min	0.71	0.69
Max	9.80	9.06
Mean	3.60	3.42
Median	3.09	3.32
Standard deviation	1.87	1.62
P-value	0.46	

This study measured the length between the SON/SOF and two anatomical points: the nasal midline and the frontozygomatic point. Statistical analysis revealed that males displayed significantly larger SON/SOF-NM distances than females ($p = 0.008$). The distance from SON/SOF to the frontozygomatic point ranged from 21.79 mm – 35.67 mm (mean: 28.42 mm ± 3.00) in females. The corresponding distance in males ranged from 23.08 mm – 40.36 mm (mean: 29.83 mm ± 2.80) and was statistically greater than the distance from SON/SOF to the frontozygomatic point in females ($p = 0.002$).

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TABLE VII: SOF/SON POSITION IN MALES VS FEMALES

	Distance to nasal midline (NM-SOF) (NM-SON) (mm)		Distance to frontozygomatic point (SOF-FZR) (SON-FZR) (mm)	
	Females	Males	Females	Males
Min	17.96	17.30	21.79	23.08
Max	40.52	35.67	35.67	40.36
Median	26.87	28.41	28.10	29.83
Mean	26.87	28.20	28.42	29.63
P-value	0.008	0.002*		

* p-value p≤0.05

DISCUSSION

The study sought to determine the existence of various morphologies of the SON/SOF along with the dimensions of the SON/SOF and position relative to the nasal midline and frontozygomatic point, in the South African population. This was done using osteometric measurements taken with a digital vernier caliper.

Numerous studies exist, reporting on the relative position and size of the SON/SOF. In general, most studies found the notch to be more prevalent[6,8]. The presence of a foramen rather than a notch suggests that the supraorbital neurovascular bundle is in a relatively stable position and thereby at greater risk during surgical dissection, as it is more likely to be stretched during retraction. Therefore, extra care must be exercised during the reflection of flaps, where the supraorbital foramen is present[9]. According to Tomaszewska *et al*[10], the frequency of SON is greater in warmer climate regions than in cold regions. The study identified a high frequency of SOF (35.4%) in cold climates and a low frequency of SOF (18.8%) in warm conditions. The frequency of SON was greater in warm climates (59%) and lowest in cold climates (44%). This would provide a larger exit route for the supraorbital vessels and may be due to thermoregulatory processes. The supraorbital vein is more exposed and therefore susceptible to heat loss when passing through the SON10. The warm climatic conditions could be a possible factor in the greater frequency of SON than other exit passageways in our study.

Without the SON/SOF, the supraorbital vasculature is more susceptible to injury due to the sharp supraorbital margin[9]. According to Tezer *et al*[11], the foramen and absent SON/SOF cannot be palpated, however, the notch can be palpated during physical examination. In our study, 19% of cases identified an absence of SON/SOF, in the South African population. The risk of neurovascular damage is thus greater in subperiosteal interventions, such as endoscopic facelifts and migraine surgeries, when there is an absence of SON/SOF[11].

Very few studies have reported the incidence of double notches. Hong *et al*[12] conducted a study using 3D CT images and identified 0.8% double notches on the right side and 0.4% on the left side. In this study, only 3.7% of double notches were found on the right side in females, which is considerably higher than the study conducted by Hong *et al*[12]. There were no double foramen identified in males, which is similar to the study conducted by Hong *et al*[13]. Knowledge of the presence of accessory foramina is important to surgeons as additional nerve bundles may emerge from these openings. The occurrence of accessory supraorbital nerves may render anaesthetic blocks unsuccessful[13].

The size of the SON/SOF in this study is smaller in diameter than in other studies[5,6]. The difference in our findings might be due to population affinity differences between the studied population15. No significant differences were found between the left and right sides, in our study.

This indicates that our study had a greater SON-NM / SOF-NM distance than other studies[6,8]. In addition, Ilayperuma *et al*[6] described sex differences in the position of SON/SOF, in agreement with our study. The study emphasized the importance of applying anatomical variation data to each subject within a population[6]. Males displayed a significantly greater SON-NM / SOF-NM distance than females, in our study. On average, female individuals are smaller in cranial size and overall more gracile in comparison to males. Del Bove *et al*[15] explained that the glabellar region, nasal region and supraorbital torus are sexually dimorphic[15]. This may explain the greater SON-NM / SOF-NM distance in males than females.

Ashwini *et al*[5] reported a mean of 29.34 mm ± 0.32 on the right, and 28.7 mm ± 0.29 on the left side. Voljevica *et al*[9] found a mean of 28.30 mm ± 2.56 in males and 27.16 mm ± 2.74 in females. These findings indicate that the data does not deviate markedly from previous studies. Ashwini *et al*[5] suggested SON-FZR / SOF-FZR to be a more reliable parameter, as it can be accurately located on the skin. The frontozygomatic suture can be palpated on the skin at a notch along the lateral orbital margin, along the plane of the end of the palpebral fissure[5].

In our study, the distances of SON-NM / SOF-NM and SON-FZR / SOF-FZR were significantly larger in males than females. Similar findings of shorter distance in females than males have been previously reported by Agthong *et al*[16], whereby NM-SOF was smaller on the left side in females. Thus, our findings suggest that sex should be considered when locating SON/SOF, as the distance to midline may be greater in males than in females[16]. The shape of the human cranium and distribution of the supraorbital structures may be influenced by genetic and environmental factors[14].

Palamenghi et al[17] explored the potential of cranial non-metric traits, such as SON/SOF. The study determined that SON/SOF was not sufficiently unique to be regarded as individualizing. Whilst our study did identify significant positional differences of SON/SOF, between males and females, a larger sample size is required to evaluate the accuracy of this tool, as a sex estimator[18]. When this data is available, the morphological features and positional data may be used for sex estimation, or to narrow down potential matches and strengthen tentative or presumptive identifications, in conjunction with other methods.

Based on the findings, it is recommended that surgeons operating in the supraorbital region consider the following guidelines:

1. Pre-operative examination must include palpation in the supraorbital region to identify SON/SOF, as the SON is a palpable structure.
   a. If SON is palpated–maintain a 2mm safety zone around the area.
   b. If no SON is palpated and there is a risk of injury to structures based on the procedure performed – consider using adjunct tools (CT/CBCT/MRI imaging) as appropriate.

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   c. If no obvious SON/SOF is identified ensure informed consent and comprehensive counselling of the patient regarding greater risk of injury to structures in the region is obtained.
2. Reference points measured (i.e., nasal midline and frontozygomatic point) can aid intraoperative orientation as well as planning surgical incision placement and needle insertion for nerve blocks.
3. Consider location variations of SON/SOF amongst sexes.
4. If an unsuccessful or incomplete nerve block is encountered, one should consider the possibility of accessory foramina or the absence of foramen or notch.
5. Careful dissection techniques and possible use of magnifying aids/loupes/nerve stimulators to aid in dissection, and prevent injury.

South Africa has a highly diverse population, comprising of different ethnic and genetic backgrounds. Morphometric studies provide insight into craniofacial variations, specific to this population, and can assist in surgical planning and improve treatment outcomes. Accurate anatomical knowledge of the neurovascular architecture and foramina localisation in the supraorbital region can help avoid iatrogenic injury during the administration of local anaesthetic, retraction of musculocutaneous scalp flaps or surgical dissection of the supraorbital region.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report.

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CPD questionnaire on page 570

The Continuing Professional Development (CPD) section provides for twenty general questions and five ethics questions. The section provides members with a valuable source of CPD points whilst also achieving the objective of CPD, to assure continuing education. The importance of continuing professional development should not be underestimated, it is a career-long obligation for practicing professionals.