RESEARCH / ARAŞTIRMA
DOI: 10.26650/IUITFD.1340706
İst Tıp Fak Derg 2024 / J Ist Faculty Med 2024

# AN INVESTIGATION REGARDING NUTRIENT FORAMEN OF THE RADIUS

## RADIUS'UN FORAMEN NUTRİCİUM'U İLE İLGİLİ BİR ARAŞTIRMA

Elif TOKLU[1,2,3], Latif SAĞLAM[3], Osman COŞKUN[3], Ahmet ERTAŞ[4], Özcan GAYRETLİ[3]

[1]İstanbul Health and Technology University, Faculty of Medicine, Department of Anatomy, İstanbul, Türkiye
[2]İstanbul University, Institute of Graduate Studies in Health Sciences, Faculty of Medicine, Department of Anatomy, İstanbul, Türkiye
[3]İstanbul University, İstanbul Faculty of Medicine, Department of Anatomy, İstanbul, Türkiye
[4]İstanbul University-Cerrahpaşa, Cerrahpaşa Faculty of Medicine, Department of Anatomy, İstanbul, Türkiye

**ORCID IDs of the authors:** E.T. 0000-0002-4429-4931; L.S. 0000-0001-6796-7484; O.C. 0000-0002-0337-4927; A.E. 0000-0002-5518-4834; Ö.G. 0000-0001-7958-3170

**Cite this article as:** Toklu E, Sağlam L, Coşkun O, Ertaş A, Gayretli Ö. An investigation regarding nutrient foramen of the radius. J Ist Faculty Med 2024;87(2):121-126. doi: 10.26650/IUITFD.1340706

### ABSTRACT

**Objective:** Arteries that provide nutrition to the long bones pass through openings called nutrient foramen (NF). The number of studies on NFs of the radius is quite scarce. Therefore, this study aimed to determine the presence, number, direction, and anatomical localization of NFs of the radius.

**Material and Method:** A total of 133 dry adult human radii were investigated in this study. The presence, number, position, and direction of NFs of the radii were determined. The shortest distance of NF to the most proximal point of the radius (DPE), the transverse diameter of the radius at the level of the NF (TD), and the shortest distance of the NF to the most prominent point of the dorsal tubercle (DDT) were measured. Furthermore, the foraminal index (FI) was calculated.

**Result:** A single NF was found in 130 (97.7%) bones, and 3 (2.3%) radii did not have NF. The NFs were most commonly on the anterior surface (80%, 104 bones) and middle 1/3 (78.5%, 102 bones) part of the bones. All NFs were towards the elbow. The DPE, TD, and DDT were meanly 82.72±11.4 mm, 129.99±15.41 mm, and 14.6±1.97 mm, respectively. The average FI was 35.6±4.64.

**Conclusion:** This paper provides additional information, such as the distance of nutrient foramen to the dorsal tubercle. Our results may help clinicians during applications related to the NF of the radius.

**Keywords:** Nutrient foramen, radius, foraminal index

### ÖZET

**Amaç:** Uzun kemiklerin beslenmesini sağlayan arterler, foramen nutricium (FN) adı verilen açıklıklardan geçer. Radius'taki FN'ler ile ilgili yapılan çalışma sayısı oldukça azdır. Bu nedenle,bu çalışmada FN'lerin radius üzerindeki varlığını, sayısını, yönünü ve anatomik lokalizasyonunu belirlemek amaçlanmıştır.

**Gereç ve Yöntem:** Bu çalışmada toplam 133 adet yetişkine ait kuru radius kemiği incelendi. FN'lerin radius üzerindeki varlığı, sayısı, konumu ve yönü belirlendi. FN'nin radius'un en proksimal noktasına olan en kısa mesafesi (PM), FN'nin bulunduğu seviyedeki transvers çap (TÇ), FN'nin tuberculum dorsale'nin en belirgin noktasına olan mesafesi (TDM) ölçüldü. Ayrıca foraminal indeks (FI) hesaplandı.

**Bulgular:** 130 (%97,7) radius'ta tek FN vardı, 3 (%2,3) radius'ta ise FN yoktu. FN'ler en sık radius'un facies anterior'unda (%80; 104 kemik) ve orta 1/3 (%78,5; 102 kemik) kısmındaydı. Tüm FN'lerin yönü dirseğe doğruydu. PM, TÇ ve TDM sırasıyla ortalama 82,72±11,4 mm, 129,99±15,41 mm ve 14,6±1,97 mm olarak hesaplandı. Ortalama FI 35,6±4,64 olarak kaydedildi.

**Sonuç:** Bu çalışma, nutrient foramenin dorsal tüberküle olan uzaklığı gibi ek bilgiler sağlamaktadır. Çalışma sonuçlarımızın, radius'taki FN ile ilgili uygulamalarda klinisyenlere yardımcı olacağı öngörülmektedir.

**Anahtar Kelimeler:** Foramen nutricium, radius, foraminal indeks

**Corresponding author/İletişim kurulacak yazar:** Latif SAĞLAM – latif.saglam@istanbul.edu.tr

**Submitted/Başvuru:** 10.08.2023 • **Revision Requested/Revizyon Talebi:** 29.01.2024 •
**Last Revision Received/Son Revizyon:** 28.02.2024 • **Accepted/Kabul:** 29.02.2024 • **Published Online/Online Yayın:** 18.03.2024

## INTRODUCTION

The nutrient foramen (NF) is the opening through which blood vessels play a role in the arterial supply and growth of bones (1, 2). One or two nutrient arteries supply the bone tissue by passing through the NF in an oblique course from the body to the bone. The entry and angulation positions of the NFs rarely vary, and the location is far from the epiphysis (3).

The anterior interosseus artery mainly provides the arterial supply of the forearm bones, and this artery supplies the radius through its branch, called the nutrient artery of radius (4, 5). The nutrient artery of the radius can branch from the posterior interosseous artery (5). Knowing the localization of the foramina is quite important as it will facilitate surgical procedures (6).

The healing process in sharps injuries or fractures depends on the arterial nutrition of the bone (2). During the healing process of bone fractures, bone nutrition plays a vital role in preventing complications that may develop. Therefore, the nutrient artery is important in fracture healing (7). Some studies also indicate that problems related to the union in fractures of the forearm bones may be caused by NF (8, 9).

When the studies in the literature are examined, there are few studies regarding the NF of the radius diaphysis, and the number of parameters evaluated is limited. This study aimed to evaluate the presence, number, direction, localization, and topography of the NF of the radius because of its clinical importance.

## MATERIALS and METHODS

In this cross-sectional study, a total of 133 radii (66 right, 67 left) from adult human skeletons of unknown age, sex, and race found at the Department of Anatomy, İstanbul University, İstanbul Faculty of Medicine, were used. None of the radii had any pathology that would affect the measurements. Ethical approval was obtained from the Clinical Research Ethical Committee of İstanbul University İstanbul Faculty of Medicine (Date: 25/06/2021, No: 13). The following parameters related to the NF of the radius were analyzed with the naked eye:

The number and patency of the NFs were noted.

The direction and localization of the NFs were recorded.

To determine the NFs' patency and direction, an acupuncture needle with dimensions of 0.25X30 mm was used. Any openings smaller than the size of the mentioned acupuncture needle were not evaluated.

The localization of the NF was determined, i.e., on which of the three margins (anterior, interosseus, and posterior margins) and three surfaces (anterior, medial, and lateral surfaces) of the radius was the NF located.

Afterward, the following measurements were also performed on the radius with a digital caliper accurate to 0.01 mm (INSIZE Co., Ltd., Taiwan):

**Total length (TL):** The shortest distance between the most proximal and distal points of the radius (Figure 1A).

**Distance to proximal end (DPE):** The shortest distance of the NF to the most proximal point of the radius (Figure 1A).

**Transverse diameter (TD):** The transverse diameter of the radius at the level of the NF is shown in Figure 2.

**Distance to dorsal tubercle (DDT):** The shortest distance of the NF to the most prominent point of the dorsal tubercle (Figure 1B).

Additionally, the topography of the NFs was evaluated as it was located on the proximal 1/3, middle 1/3, and distal 1/3 of the total length of the radius. Calculations were made using the foraminal index (FI) formula defined by Hughes (10) to determine the topography of the NFs. The formula defined by Hughes is as follows: FI = (DPE/TL) x 100.

Two independent researchers performed the morphometric measurements, and the mean value per parameter was recorded. Both measurements were repeated if there was more than a 10% difference between the two measurements. The digital caliper was calibrated before each measurement to provide accurate calculations. The

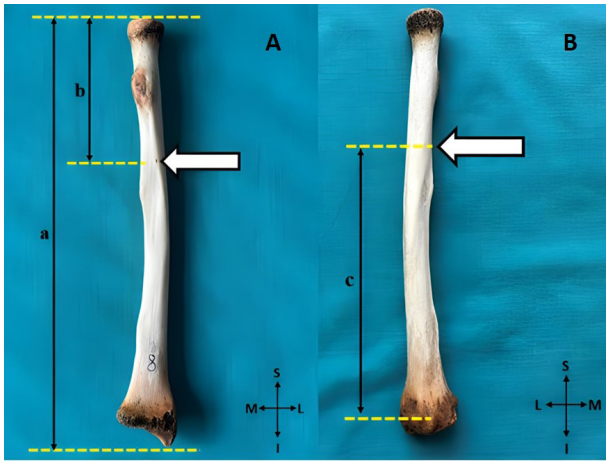


**Figure 1:** Some morphometric measurements. A. Representation of the measurement of TL and DPE of the radius B. Representation of the measurement of DDT of the radius. a: Total length (TL), b: Distance to proximal end (DPE), c: Distance to dorsal tubercle (DDT), NF: Nutrient foramen, S: Superior, I: Inferior, M: Medial, L: Lateral. The white arrow shows the nutrient foramen.

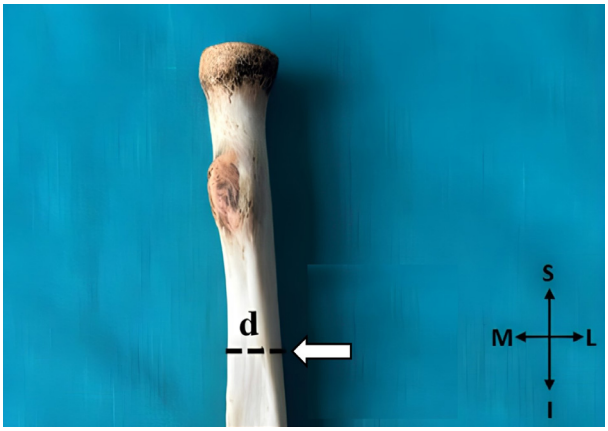


**Figure 2:** The transverse diameter of the radius at the level of the NF. d: Transverse diameter (TD), NF: Nutrient foramen, S: Superior, I: Inferior, M: Medial, L: Lateral. The white arrow shows the nutrient foramen.

mean and standard deviation of all morphometric parameters were calculated using SPSS 21.0 (IBM SPSS Corp., Armonk, NY, USA). Morphometric measurements of all evaluated parameters are shown in Figure 1 and Figure 2.

## RESULTS

Of the 133 radii, 3 of them (1 right, 2 left) had no NF, whereas 130 had a single NF (Figure 3). The direction of all NFs was towards the elbow (Figure 3). The NFs were most frequently located on the anterior surface and least frequently on the anterior margin of the radius (Figure 3A). No NF existed on the posterior margin and lateral surface of the radius.

Localization of the NF on the radii is shown in Figure 3. In total, of the 130 NF, the TL, DPE, TD, and DDT values


**Figure 3:** Localization of the NF of the radii. A. Radius with the NF on the anterior surface, B. Radius with the NF on the anterior margin, C. Radius with the NF on the posterior surface, D. Radius with the NF on the interosseus margin, NF: Nutrient foramen, S: Superior, I: Inferior, M: Medial, L: Lateral.

were 227.09 mm, 82.72 mm, 14.6 mm, and 129.99 mm, respectively. Of the total 130 foramina, 28 were located on the proximal 1/3 of the bone, and the rest (102) were located on the middle 1/3. In other words, no NF was observed on the distal 1/3. The mean FI was 35.6. All morphometric measurements regarding the NFs are detailed in Table 1 and Table 2.

**Table 1:** Number, topography, and localization of NF

| Nutrient Foramen (NF) | | Number of radii n (%) |
|---|---|---|
| Number of NF | 0 | 3 (2.3) |
| | 1 | 130 (97.7) |
| Localization of NF | Anterior surface | 104 (80) |
| | Posterior surface | 5 (3.9) |
| | Interosseus margin | 15 (11.5) |
| | Anterior margin | 6 (4.6) |
| Topography of NF | Proximal 1/3 | 28 (21.5) |
| | Middle 1/3 | 102 (78.5) |
| | Distal 1/3 | - |

## DISCUSSION

### The number and direction of nutrient foramina

A brief review of the literature regarding the number and direction of nutrient foramina is shown in Table 3 (8, 7, 11-17). In our study, NF was not found in 2.3% (3 bones), and 97.7% (130 bones) had a single NF out of a total of 133 radii. Nevertheless, we did not observe a radius with 2 NF. In previous studies, one conducted by Güner et al. and the other by Öztürk et al., the rate of the radius with 2 NF was reported as 2% (1 bone) and 12.3% (6 bones), respectively (15, 7). Most authors agree that a single nutrient foramen is in the radius (Table 3). Parmar et al. and Reddy et al. observed that the radius with a single NF was 96.6% (58 bones) and 96.3% (52 bones), respectively (8, 14). Our results regarding a single NF are compatible with the results of a single NF of these two previous studies.

Öztürk et al. assessed 49 radii and reported that 96.36% of NFs were towards the elbow, and 3.64% of NFs were towards the wrist (7). On the other hand, Patel et al. stated that all directions of NFs were toward the elbow in their study, with 40 radii (13). All of the 130 foramina evaluated in this study were towards the elbow.

It has been shown that radius fractures coinciding with the NF level may cause severe arterial nutrition loss, which may progress to bone ischemia (9). Since most of the radii we analyzed had a single NF, a fracture at the

**Table 2:** The morphometric data of 130 radii with single nutrient foramen

| | Total length | Distance to proximal end | Transverse diameter | Distance to dorsal tubercle | F Index |
|---|---|---|---|---|---|
| Minimum | 186.11 mm | 61 mm | 11 mm | 90 mm | 27.04 |
| Maximum | 266 mm | 121 mm | 21.96 mm | 170.28 mm | 49.59 |
| Mean | 227.09 mm | 82.72 mm | 14.6 mm | 129.99 mm | 35.6 |
| Standard deviation | 17.77 mm | 11.4 mm | 1.97 mm | 15.41 mm | 4.64 |

TL: Total length, DPE: Distance to proximal end, TD: Transverse diameter, DDT: Distance to dorsal tubercle

**Table 3:** The current review of the literature regarding the number and direction of nutrient foramina and our study

| Study | Year | Number of radius | Number of NF | | | Direction of NF | Localization of NF | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 1 | 2 | | AS | PS | AB | IB | Proximal 1/3 | Middle 1/3 | Distal 1/3 |
| Ukoha et al. (11) | 2013 | 50 | 16 (32%) | 34 (68%) | - | Elbow (except 1 NF) | 16 | 3 | 11 | 5 | 20 | 15 | - |
| Parmar et al. (8) | 2014 | 60 | - | 58 (96.6%) | 2 (3.4%) | Elbow | 35 | 5 | 4 | 2 | - | - | - |
| Solanke et al. (12) | 2014 | 80 | 4 (5%) | 74 (92.5%) | 2 (2.5%) | - | 53 | 4 | 6 | 17 | - | - | - |
| Patel et al. (13) | 2015 | 40 | - | 40 (100%) | - | - | 35 | 5 | - | - | - | - | - |
| Reddy et al. (14) | 2016 | 54 | - | 52 (96.3%) | 2 (3.7%) | - | 49 | 1 | - | 4 | - | - | - |
| Güner et al. (15) | 2019 | 50 | 12 (24%) | 37 (74%) | 1 (2%) | - | 33 | 1 | 2 | 3 | - | - | - |
| Mishra et al. (16) | 2019 | 38 | - | - | - | Elbow | - | - | - | - | 9 | 28 | - |
| Challa et al. (17) | 2019 | 50 | - | 50 (100%) | - | Elbow | 35 | - | - | 15 | 13 | 37 | - |
| Öztürk et al. (7) | 2021 | 49 | - | 43 (87.7%) | 6 (12.3%) | 96.36% Elbow | | | | | 25 | 30 | - |
| Present study | 2023 | 133 | 3 (2.3%) | 130 (97.7%) | 0 | Elbow | 104 | 5 | 6 | 15 | 28 | 102 | - |

AB: Anterior margin, AS: Anterior surface, IB: Interosseus margin, NF: Nutrient foramen, PS: Posterior surface

NF level may increase the risk of arterial nutritional loss. Besides, we think that knowledge that the direction of all NFs is towards the elbow may facilitate detection and imaging techniques and the application of interventional procedures of NFs.

**Location of nutrient foramina**

In this study, the most common location was on the anterior surface of the radius (104 NFs), followed by the interosseus margin (15 NFs) and anterior margin (6 NFs). The least common localization was on the posterior surface of

**Table 4:** The morphometric results of previous studies and our results

| Study | Year | TL (mm) | DPE (mm) | TD (mm) | DDT (mm) | FI |
|---|---|---|---|---|---|---|
| Solanke et al. (12) | 2014 | 229.4±21.5 | - | 13.03±1.68 | - | - |
| Veeramuthu et al. (18) | 2017 | 248.5+14 | - | | - | 33.78±4.64 |
| Güner et al. (15) | 2019 | 227.6 | 81.5 | - | - | 35.9 |
| Mishra et al. (16) | 2019 | 226.7+14.66 | - | - | - | - |
| Öztürk et al. (7) | 2021 | 228.39±15.87 | 77.88±16.95 | - | - | 34.11±7.08 |
| Present study | 2023 | 227.09±17.77 | 82.72±11.4 | 14.6±1.97 | 129.99±15.41 | 35.6±4.64 |

TL: Total length, DPE: Distance to proximal end, TD: Transverse diameter, DDT: Distance to dorsal tubercle, FI: Foraminal Index

the radius (5 NFs). Our results are similar to the results of studies in the literature.

The anterior interosseus artery, the main artery providing endosteal and periosteal supply to the radius, is very important in transplantation and reconstruction surgery to reduce the incidence of pseudoarthrosis (5). The fact that the nutrient artery of the radius can also originate from the posterior interosseus artery can explain why some NFs are located on the posterior surface of the radius (5). To preserve nutrient arteries during surgery, it is important to know the course of the artery and the anatomical localization of the NF in the long bones (7).

**Morphometric features and topography of nutrient foramina**

In our study, we measured the total length (TL), distance to the proximal end (DPE), transverse diameter (TD), distance to dorsal tubercle (DDT), as well as the foraminal index (FI). We have reviewed the current literature about these parameters, as shown in Table 4 (7, 12, 15, 16, 18). In the present study, the mean TL and DPE were 227.09±17.77 mm and 82.72±11.4 mm, respectively. We also calculated the mean FI as 35.6±4.64. Our results are almost the same as those of the studies of Güner et al. (15).

The TD was 14.6±1.97 mm in this study. Solanke et al. obtained the value of 13.03±1.68 mm, which is very close to our TD value (12). Some studies have indicated that the transverse diameter of the radius is correlated with the anteroposterior diameter of the radius (19). With this information, the diameters of the radius are interpreted, and the length of the screw to be applied in distal radius fractures can be decided (19). The diameter data of the radius obtained in our study may also help practitioners.

The DDT value was 129.99±15.41 mm in our study. We could not find any studies that measured DDT value. In order to perform surgical procedures in a safe framework, some landmarks are utilized. For example, in forearm fractures, surgical planning concerns certain landmarks, such as the styloid process and radial tuberosity (20). In addition, these landmarks guide surgeons in imaging techniques (20). The dorsal tubercle is one of the palpable landmarks on the radius. We measured the distance of the NF to the radius's dorsal tubercle, which might be a good landmark for surgical application. We believe this value might be a helpful guide for surgeons in applications related to the NF. Furthermore, we think that having such information about the NF may reduce the development of the risk of complications related to NF surgery.

In their studies, Kızılkanat et al. pointed out that the majority of NFs were located on the proximal half of the radius (1). They also recorded that the NF was found between 22.2-46% of the total length of the radius (1). Murlimanju et al. reported that the NF was between 26-46% of the total length of the radius, and Campos et al. reported that it was between 25-50% (5, 21). We evaluated 130 NFs in this study and detected that 28 NFs were located on the proximal 1/3 and 102 NFs were on the middle 1/3 of the bones. We believe surgeons should focus on the latter location when planning operations with NFs. Thus, the planned surgical time related to NFs may be shortened, which may help prevent complications.

As a result, as new surgical techniques develop (such as microvascular bone transfer), the anatomical structure of the NF gains importance (1, 5, 12, 22). In this respect, knowing the morphometric values of the NF may be necessary to protect radius circulation.

The limitation of this study was the lack of age and gender information on the radii. We would have discussed more significant results if we accessed this information.

## CONCLUSION

In this study, a total of 133 radii were examined morphometrically. Although many findings showed results similar to those of previous studies, unlike in previous studies, the distance of the nutrient foramen to the dorsal tubercle was measured. The current study's findings might contribute to the literature on clinical applications related to the nutrient foramen of the radius.

**Ethics Committee Approval:** The study has ethical approval from the İstanbul University İstanbul Faculty of Medicine (Date: 25.06.2021, No: 13).

**Peer Review:** Externally peer-reviewed.

**Author Contributions:** Conception/Design of Study- E.T., L.S.; Data Acquisition- E.T., A.E.; Data Analysis/Interpretation- O.C., Ö.G.; Drafting Manuscript- E.T., L.S., O.C.; Critical Revision of Manuscript- O.C., A.E., Ö.G.; Final Approval and Accountability- E.T., L.S., O.C., A.E., Ö.G.

**Acknowledgement:** We are so grateful to Melih TOKLU for his valuable contributions to preparing the figures.

**Conflict of Interest:** The authors have no conflict of interest to declare.

**Financial Disclosure:** The authors declared that this study received no financial support.

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