Color doppler ultrasound for the assessment of palatal fibromucosa thickness and the trajectory of the greater palatine artery: A pilot study

Raúl Sampietro-Martínez 1, Javier Pérez-Monreal 2, Alba Sánchez-Torres 3, Javier Bara-Casaus 4, Cosme Gay-Escoda 5

1 DDS, MS. Master Degree Program in Oral Surgery and Orofacial Implantology (EFHRE International University/FUCSO)
2 MD, MSc, PhD, EBPh. Director of the Department of Vascular Doppler Ultrasound, MAZ Hospital. Zaragoza, Spain. Associate Professor of the Master Degree Program in Phlebology and Lymphology, University of Alcalá. Madrid, Spain
3 DDS, MS. Master of Oral Surgery and Orofacial Implantology. Associate Professor of the Oral Surgery Department, School of Dentistry, University of Barcelona, Spain
4 MD, PhD, OMFS. Director of the Maxillofacial Institute of Sagrat Cor University Hospital, Barcelona, Spain. Co-Director of the Specialist Course in TMJ and Orofacial Pain, University of Barcelona. Director of the Postgraduate Course in Oral Medicine and Surgery of the Catalan Society of Odontology and Stomatognathy
5 MD, DDS, MS, PhD, EBOS, OMFS. Chairman and Professor of the Oral and Maxillofacial Surgery Department, School of Dentistry, University of Barcelona. Director of the Master Degree Program in Oral Surgery and Implantology (EFHRE International University / FUCSO). Coordinator/Researcher of the IDIBELL Institute. Head of the Oral and Maxillofacial Surgery and Implantology Department, Teknon Medical Center, Barcelona, Spain

Correspondence:
C/ Feixa Llarga, s/n; Pavelló Govern 2ª planta, Despatx 2.9
08907 - L’Hospitalet de Llobregat (Barcelona)
Spain
albaschez@gmail.com

Abstract

Background: The primary objective of this study was to determine the position and course of the greater palatine artery using color doppler ultrasound. The secondary objective was to determine the thickness of the palatine fibromucosa.

Material and Methods: A pilot case series study was performed in a private clinic during February 2020. The scans were performed with a Mindray® M9 ultrasound machine (Mindray North America, NJ, USA) coupled to an L16-4Hs® hockey-type angled probe. For each participant, the arterial path and thickness of the palatal fibromucosa were determined at 5 different points.

Results: A total of 6 volunteers (3 males and 3 females) with a mean age of 39.2 (±16) years were included. While the thickness of the fibromucosa decreased along the anterior area, the distance from the cementoenamel junction to the position of the artery was generally maintained up to the canine position, where it was found to be closed to teeth.

Conclusions: Color doppler ultrasound allows accurate localization of the artery as well as measurement of the thickness of the palatine fibromucosa. It would help to select the best area for graft harvesting in order to avoid bleeding complications due to vascular sectioning.

Key words: Hard palate, doppler ultrasonography, diagnosis, connective tissue graft.
Introduction

Soft tissue autografts through the addition of keratinized gingiva and/or connective tissue are widely used in periodontics and oral surgery both for the treatment of gingival recessions and for gaining volume in oral rehabilitations by means of osseointegrated implants. The palate is the most frequent donor site for the procurement of these autografts, either the free gingival graft - a surgical technique described by Sullivan and Atkins (1) and later modified by Miller (2), or the subepithelial connective tissue graft, described by Langer and Langer (3).

Before harvesting the autograft, it is advisable to palpate the palatal bony sulcus containing the neurovascular bundle, with the aim of establishing an apical limit of the incision in order to avoid sectioning this anatomical structure. The neurovascular bundle containing the greater palatine artery (GPA) emerges through the greater palatine foramen at the level of the second and third molars, approximately at the midpoint between the bony crest and the palatal raphe, and running after its emergence in an anterior direction. It is also convenient to measure the thickness of the palatal fibromucosa in order to know the volume of tissue available to cover the receptor area. In this sense, Miller (2) recommended a minimum thickness of the palate of 4 mm for connective tissue grafts. Regarding the volume of the graft, Allen (4) concluded that a considerable volume of graft (from 1.5 mm in thickness) seems to produce a higher survival rate.

Reiser (5) described some measures of GPA location in relation to the cementoenamel junction (CEJ). When the donor area is located in a low or flat palatal vault, the artery is normally located in a position closer to the CEJ (about 7 mm). In mid-palates it is located about 12 mm from the CEJ, and in case of U-shaped or ogival palates the distance is approximately 17 mm. In another study by Yu et al. (6), the most appropriate donor site for the procurement of gingival autografts was found to be the region between 3-9 mm below the CEJ, between the distal surface of the canine and the midline surface of the first molar. However, the localization of the GPA by these measurements does not always yield the expected result, and sometimes the GPA is sectioned and may cause profuse bleeding during and after surgery.

There are pilot studies (7,8) that measure the thickness of the palatine fibromucosa and the location of the palatine artery by means of magnetic resonance imaging (MRI). Hilgenfeldt et al. (7) evaluated whether high-resolution, non-contrast dental MRI could be used for the accurate determination of palatal fibromucosa thickness and for localization of the GPA. They observed that the thickness of the palatal fibromucosa measured by MRI was comparable to that obtained by bone probing. These authors therefore concluded that dental MRI allows reliable, noninvasive, radiation-free planning to preope-
Color doppler ultrasound for oral use

The primary objective of this study was to determine the exact position and trajectory of the GPA using color doppler ultrasound. The secondary objective was to determine the thickness of the palatine fibromucosa.

Material and Methods

This manuscript was written in accordance with the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) statement (25). The present work is a pilot case series study from a private clinic conducted during the month of February 2020. The study protocol was approved by the Clinical Research Ethics Committee of Aragón (CEICA) (Spain) with minute number 02/2020. All patients signed an informed consent for participation in the study and performance of the ultrasound examinations. To be included, patients had to be of legal age, and the exclusion criteria were the presence of any oral or systemic disorder with repercussions upon the palatal fibromucosa.

Intraoral ultrasound scans to determine the course of the GPA as well as the thickness of the palatine fibromucosa were performed with a Mindray® M9 ultrasound scanner (Mindray North America, NJ, USA) coupled to an L16-4Hs® hockey-type angled ultrasound probe for musculoskeletal, superficial, neurological and vascular applications. The exact characteristics of the probe can be seen in Table 1. The scans were performed by a specialist in vascular ultrasound (JPM) who collaborated in carrying out the study. The scans were performed using a frequency of 13.5 MHz in B-mode and 6.6 MHz in color doppler mode. Hyaluronic acid gel was used for correct displacement and image capture by the ultrasound probe.

To determine the path of the GPA, 5 reference points were established as shown in Figure 1: origin of the GPA (O), midpoint of the first molar (1), midpoint of the second premolar (2), midpoint of the first premolar (3), and midpoint of the canine (4). The ultrasound probe was used to locate the emergence of the neurovascular bundle. At each of the reference points, the presence of pulsatile blood flow (velocimetry curve) and the doppler effect were determined. Once these two features were located, the image of the arterial segment was centered and made to correspond with the center of the probe, thus ensuring that the tissue underlying the probe contained the GPA, and the image provided by the ultrasound scanner was recorded. Using the ultrasound measuring system, the thickness of the fibromucosa (distance from the epithelium to the palatal cortex) was measured at each of the preset points (Fig. 2), and the path of the GPA (distance from the CEJ to the reference point) was marked with a Tondaus® gentian violet surgical marker (Kapok Stationery Co., Guangdong, China). In order not

| Bandwidth          | 3.5-16 MHz (-20 Db) |
|--------------------|---------------------|
| Number of elements | 128                 |
| Maximum field of view | 25.3 mm            |
| Head dimensions    | 6 mm x 28.8 mm      |
| B-mode frequencies | 5.4-11.6, 6.0-12.6, 6.6-13.5 MHz |
| Harmonic frequencies | 8.0, 10.0, 12.0 MHz |
| Color doppler frequencies | 5.0, 5.7 MHz |
to lose the reference of the arterial position, the tip of a periodontal probe was rested just at the point where the artery had been located with the ultrasound probe. This maneuver was performed without lifting the ultrasound probe completely so as not to lose the reference of the exact point where the artery was located.

**Results**
A total of 6 volunteers (3 men and 3 women) with a mean age of 39.2 (±16) years were included in the study, obtaining a total of 30 ultrasound images (5 images per participant) of the preset points.

Firstly, the emergence of the GPA was located. Next, the velocimetry curve and the doppler effect were determined at each of the reference points, as shown in Figure 3. As the exact area where the artery was located was recorded, the path was marked with the surgical marker. Table 2 reports the thickness of the palatal fibromucosa at the different points for each participant. The results show a progressive decrease in thickness from point O to the most anterior area.

Table 3 shows the path of the GPA measured as the distance from the CEJ to the artery at each of the preset points. It only shows a slight decrease in distance from the most posterior to the most anterior positions. In fact, the distance was overall maintained up to point 4, i.e., at canine level, where the GPA lies closer to the teeth. Once we had located and marked the 5 points corresponding to the course of the GPA with the surgical marker, we took an intraoral photograph of the course of the artery in each of the participants (Fig. 4).

**Discussion**
The thickness of the palatine fibromucosa had been previously explored using B-mode ultrasound techniques (23,24). However, to our knowledge, this is the first study using color doppler ultrasound to locate and map the course of the GPA. The study by Schulze et al. (23) explored the thickness of the fibromucosa by ultrasound at a single point per patient at the level of the molars. Other studies on masticatory mucosal thicknesses (26,27) have scanned a larger number of points per patient. These studies scanned the mucosa of the canine, first premolar, second premolar, first molar and second premolar at 3, 6, 9 and 12 mm from the CEJ. However, they were performed using 3D radiology and not ultrasonography, since it is technically easier to measure more points through radiographic means than through ultrasound. In our study we evaluated the thickness of the fibromucosa at the sites where the artery was located in each of the preset areas (first molar, second premolar, first molar and canine). During the ultrasound measurements, we encountered a series of problems or difficulties regarding handling of the ultrasound probe in the oral cavity. It should be remembered that the probe, although with an angled shape as proposed in the study by Palou et al. (18), and being one of the smallest ultrasound probes with the capacity to visualize very superficial tissues, is not specifically designed for intraoral use, since it was originally intended for dermatological, neurological, musculoskeletal and vascular use, and therefore with the capacity to work in doppler type frequen-

![Fig. 3: Velocimetry curve and doppler effect (red and blue).](image)

**Table 2: Palatal fibromucosa thickness measurements (in mm) for each of the patients included.**

| Palatal Fibromucosa Thickness | Point O | Point 1 | Point 2 | Point 3 | Point 4 |
|-------------------------------|--------|--------|--------|--------|--------|
| Patient 1                     | 9      | 5      | 5.6    | 5.4    | 5.3    |
| Patient 2                     | 8.6    | 6.8    | 7.4    | 3.5    | 2.2    |
| Patient 3                     | 4.9    | 5.3    | 4.2    | 5.4    | 2.7    |
| Patient 4                     | 7.7    | 6.4    | 4.9    | 4.2    | 2.9    |
| Patient 5                     | 6.4    | 7.5    | 6.1    | 4.8    | 6.2    |
| Patient 6                     | 7.5    | 4.1    | 3.4    | 4.2    | 3.4    |
| **Mean (SD)**                 | 7.4 (1.5) | 5.9 (1.3) | 5.3 (1.4) | 4.6 (0.8) | 3.8 (1.6) |
cies. There are specific ultrasound probes for intraoral use (24,28). However, these probes have not been used in doppler type frequencies in the oral cavity. The handling of the probe used in the present study is especially difficult in patients with an ogival palate, especially in the anterior part, which can result in distorted images of the anatomical limits (epithelium and palatal cortex) and make it difficult to fix a precise limit in the images of the anterior part of the palate. In this sense, it would be interesting to carry out studies similar to our own with specific ultrasound probes for intraoral use in order to determine whether probes of this kind make exploration of the anterior part of the palate easier for the operator. Likewise, in order to guarantee maximum precision regarding the thickness of the fibromucosa, it would be necessary to compare the results with another type of tool such as measurement of the fibromucosa with a periodontal probe. In this sense, Schulze et al. (23) already concluded that ultrasound is a method as reliable in the exploration of the fibromucosa as manual probing. The results obtained in our study, which although showing a slight progressive decrease between the CEJ and the GPA, the measurements remain constant as the palate advances (until reaching the level of the canines) are in agreement with other studies (5,29) that evaluate the trajectory of the GPA. Likewise, the doppler image and pulsatile flow can ensure its position, though it depends largely on the ability of the operator to mark it by means of a periodontal probe and surgical marker. The clinical uses which dentists can obtain from scanning prior to graft surgery are manifold. The present ultrasound technique allows a better therapeutic decision to be made regarding the use of autografts compared to other alternatives. In addition, it allows us to determine the best area for graft harvesting in order to avoid bleeding complications due to sectioning of the GPA. Of course, handling the ultrasound scanner requires a learning curve to achieve reliable results. In this sense, dentists should be specifically trained in this technique or have a specialist in this field of medicine to ensure correct exploratory results.

Conclusions
The results of this pilot study indicate that accurate localization of the GPA is possible by means of color doppler ultrasound, as well as the measurement of the thickness of the palatine fibromucosa. The technique allows a better therapeutic decision to be made regarding the use of autografts compared to other alternatives. In addition, it is able to define the best area for graft harvesting in order to avoid bleeding complications due to sectioning of the greater palatine artery.

References
1. Sullivan H, Atkins J. Free autogenous gingival grafts: principles of successful grafting. Periodontics. 1968;6:121-9.
2. Miller P. Root coverage using free soft tissue autografts following acid application. Int J Periodont Rest Dent. 1982;2:65-70.
3. Langer B, Langer L. Subepithelial connective tissue graft technique for root coverage. J Periodontol. 1985;56:715-20.
4. Allen A. Use of the supraperiosteal envelope in soft tissue grafting for root coverage. Int J Periodontol Rest Dent. 1994;14:217-27.
5. Reiser G, Bruno J, Mahan P, Larkin L. The subepithelial connective tissue graft palatal donor site: anatomic considerations for surgeons. Int J Periodontics Restorative Dent. 1996;16:130-7.
6. Yu S, Lee M, Kim C, Kim D, Kim H. Thickness of the palatal masticatory mucosa with reference to autogenous grafting: a cadaveric and histologic study. Int J Periodontics Restorative Dent. 2014;34:115-21.
7. Hilgenfeld T, Kästel T, Heil A, Rammelsberg P, Heiland S, Bendszus M, et al. High-resolution dental magnetic resonance imaging for plan-
ning palatal graft surgery—a clinical pilot study. J Clin Periodontol. 2018;45:462-70.
8. Heil A, Schwindling F, Jelinek C, Fischer M, Prager M, Lazo González E, et al. Determination of the palatal masticatory mucosa thickness by dental MRI: a prospective study analysing age and gender effects. Dentomaxillofac Radiol. 2018;47:20170282.
9. Pineda V, Macias P, Bermal G. Principios básicos del ultrasonido. Investigación en Discapacidad. 2012;1:25-34.
10. Kossoff G. Basic physics and imaging characteristics of ultrasound. World J Surg. 2000;24:134-42.
11. Baum G, Greenwood I, Slawski S, Smirnow R. Observation of internal structures of teeth by ultrasonography. Science. 1963;139:495-6.
12. Smirnow R, Wolfe M. Illumination of oral structures by pulsed ultrasound. Biol Eng. 1967;1:326-7.
13. Reich F, Brenden B, Porter N. Ultrasonic imaging of teeth. Battelle Memorial Institute; 1967.
14. Kossoff G, Sharpe J. Examination of the contents of the pulp cavity in teeth. Ultrasonomics. 1966;4:77-83.
15. Daly C, Wheeler J. The use of ultrasonic thickness measurement in the clinical evaluation of oral soft tissues. Int Dent J. 1971;21:418-29.
16. Kydd W, Daly C, Wheeler J. The thickness measurement of masticatory mucosa in vivo. Int Dent J. 1971;21:430-41.
17. Spranger H. Ultra-sonic diagnosis of marginal periodontal diseases. Int Dent J. 1871;21:442-55.
18. Palou M, McQuade M, Rossmann J. The use of ultrasound for the determination of periodontal bone morphology. J Periodontol. 1987;58:262-5.
19. Eger T, Müller H, Heinecke A. Ultrasonic determination of gingival thickness: subject variation and influence of tooth type and clinical features. J Clin Periodontol. 1996;23:839-45.
20. Müller H, Schaller N, Eger T, Heinecke A. Thickness of masticatory mucosa. J Clin Periodontol. 2000;27:431-6.
21. Müller H, Schaller N, Eger T. Ultrasonic determination of thickness of masticatory mucosa: a methodologic study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1999;88:248-53.
22. Rajpoot N, Nayak A, Nayak R, Bankur P. Evaluation of variation in the palatal gingival biotypes using an ultrasound device. J Clin Diagn Res. 2015;9:56-60.
23. Schulze R, Curić D, d’Hoedt B. B-mode versus A-mode ultrasonographic measurements of mucosal thickness in vivo. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2002;93:110-7.
24. Salmon B, Le Demnat D. Intraoral ultrasonography: development of a specific high-frequency probe and clinical pilot study. Clin Oral Investig. 2012;16:643-9.
25. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandebroucke JP. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: Guidelines for reporting observational studies. BMJ. 2007;335:806-8.
26. Song J, Um Y, Kim C, Choi SH, Cho KS, Kim CK, et al. Thickness of posterior palatal masticatory mucosa: the use of computerized tomography. J Periodontol. 2008;79:406-12.
27. Ueno D, Sekiguchi R, Morita M, Jayawardena A, Shinpo S, Sato J, et al. Palatal mucosal measurements in a Japanese population using cone-beam computed tomography. J Esthet Restor Dent. 2014;26:48-58.
28. Kwak E, Lee N, Park W, Kim K. Foreign body removal assisted by an intraoral ultrasound probe. Oral Radiol. 2019;35:73-6.
29. Yu S, Lee M, Park B, Jeon H, Chung Y, Kim J. Topographical relationship of the greater palatine artery and the palatal spine. Significance for periodontal surgery. J Periodontol. 2014;41:908-913.

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Ethical statements
Ethis approval statement: The study protocol was approved by the Clinical Research Ethics Committee of Aragón (CEICA) (Spain) with minute number 02/2020.

Patient consent statement: All patients signed an informed consent for participation in the study and performance of the ultrasound examinations.

Conflicts on interest
The authors Raúl Sampietro-Martínez, Javier Pérez-Monreal and Javier Bara-Casaus declare that they have no conflict of interest. Dr. Sánchez-Torres reports personal fees from Unither Pharmaceuticals (Paris, France) and from Mundipharma Research (Cambridge, United Kingdom), both outside the submitted work. Prof. Dr. Gay-Escoda reports personal fees from Unither Pharmaceuticals (Paris, France), from Mundipharma Research (Cambridge, United Kingdom) and Menarini Research (Florence, Italy), outside the submitted work.