Detection of the course of the greater palatine artery using the diagnostic ultrasound device

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Detection of the course of the greater palatine artery using the diagnostic ultrasound device

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이강희 씀

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Detection of the course of the greater palatine artery using the diagnostic ultrasound device

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Ultrasound diagnosis has been used very actively in the medical field up to the present since it has no radiation dose unlike the other conventional radiodiagnoses, can diagnose the soft tissue diseases, and is possible to diagnose dynamically through the probe movement. The main reason why ultrasound diagnosis has not been applied to the dental field, while it has been used in all fields of medicine, is that a probe for the dental field has not been developed and no suitable indication has been found.

The maxillary palate is a good donor site to collect the large amount of keratinized gingiva required for gingival graft or connective tissue graft, but it is necessary to exercise caution, as there is the greater palatine artery emerging from the greater palatine foramen.

The greater palatine foramen is usually located at the middle or posterior part of the second molar area. In the past, dental clinics were not equipped with the devices to observe the soft tissues and arteriovenous veins, and those devices were limited to expensive equipment such as CT, MRI, and PET. there was no other way but to depend on the anatomical average or the operator's experience to know the locations of the arteries. According to Sebastian et al. The greater palatine artery arises from greater palatine foramen and travels forward along the palatal vault, and it is known to be located on an average of 8 to 12 mm above the gingival margin of the molar. It is necessary to exercise caution since the course of the greater palatine artery may be mutated or branched, a large amount of bleeding may occur if it is damaged.

Dental radiographic image diagnosis has played a very important role in dental diagnosis. However, it has the following limitations: Radiation exposure is unavoidable, it's impossible to evaluate soft tissue disease and dynamic movement since most radiographic images are still. In addition, measuring the anatomic structures using cadavers will occur errors since the structure contracts over time, and measuring by a dental probing causes invasive and repeated pain and fear to patients, and errors occur depending on the proficiency of the operator.

In order to overcome those limitations of the existing studies, the courses of the greater palatine artery of normal Korean adults (N=40, 20-59 age range) were identified by using a diagnostic ultrasound device (Ecube 9 diamond®, Alpinion Medical System, Seoul, Korea) and a probe (IO3-12®, Alpinion Medical System, Seoul, Korea) for dental use, and the following conclusions were obtained in this study.

1. The vertical height (GM – GPA; Distance from the gingival margin to the greater palatine artery, height of the greater palatine artery) of the palatal artery of Korean adults was 14.8 ± 1.6 mm. GM-GPA of male was 14.9 ± 1.8 mm, which was significantly larger than that of female (14.24 ± 1.6 mm; $P < 0.05$).

2. GM-GPA showed differences according to teeth (from the first premolar to the second molar), but there was no statistical significance.

3. The average PG-GPA (Distance from the palatal gingiva to the greater palatine artery, depth of the greater palatine artery) of 40 Korean adults was 4.10 ± 0.51 mm, and there was no gender difference.

4. Depending on the teeth (from the first premolar to the second molar), gingival thickness was observed to increase toward the posterior.

5. Inter-examiner agreement for the measurement of both GM-GPA and PG-GPA presented excellent agreement. Each ICC(intraclass correlation) value was 0.983 (0.969-0.991) and 0.845 (0.707-0.918), respectively.

6. Palatal height was strongly correlated with the human height and GM-GPA (Spearman coefficient: 0.395, 0.327; P <0.05).

7. Multiple regression analysis indicated that arch height and arch width were significantly associated with the GM-GPA.

8. The distance of PG-GPA did not show a significant correlation with the palatal height or the arch width, or the human height.

9. Multiple regression analysis indicated that only age was found to be significantly associated with the distance of PG-GPA at the premolar area.

This study suggests the directions to utilize the dental probes in various ways and to increase the use of ultrasound in the dental field. Evaluating the oral soft tissues in a non-invasive manner is expected to contribute to safer and more assertive surgeries by reducing the patient's discomfort, the possibility of accidents during surgery, and complications after surgery.

Key Words: Ultrasound; Greater palatine artery; Palate; Gingival thickness

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Ⅰ. INTRODUCTION

Dentistry has been developed not only as a study of prevention, diagnosis, and treatment of diseases related to teeth, such as dental caries, periodontitis, or malocclusion, but also as a purpose of diagnosis and treatment of diseases that occur in various tissues such as oral mucous membranes (soft tissue), masticatory muscles (muscles), dental arch (bones), and jaw joints (articular cartilage). To treat a disease, an accurate diagnosis and treatment plan must be established. Dental diseases are easy to diagnose in the early stage since they are located in the oral cavity which is easy to inspect, and most of them are accompanied by pain. However, since bone tissues and dental tissues are very hard, there is a limited scope to accurately diagnose through regular examination and palpation.

Dental radiographic image diagnosis has played a very important role in dental diagnosis. it has the advantage of evaluating hard tissues in the oral and maxillofacial areas, such as teeth and jaws while using a relatively small amount of radiation at dental clinics. In addition to basic methods such as periapical radiographic image for a detailed evaluation of teeth and periodontal tissue, and panoramic radiographic image for the overall evaluation of the jawbone and teeth, radiographic imaging technology has been developed for various purposes such as computed tomography and cone-beam CT, which allow three-dimensional analysis.[1]

However, the following limitations still exist in radiographic diagnosis.

1) Radiation exposure is unavoidable.

2) Evaluation of dynamic movement is not possible since most radiographic images are static images.

3) Evaluation of soft tissue disease is not possible.

Ultrasonography is performed through a probe that generates ultrasonic waves when placed in close contact with the inspection area, and then the ultrasonic waves are returned to visualize the images in real-time. It is the most basic method in the imaging diagnoses since it is convenient to use, harmless to the human body, and makes the patient feel comfortable during the test.[2] In particular, it can easily and accurately evaluate the structures located on the surface of the human body, such as the breast, thyroid, and musculoskeletal. The inspection equipment of ultrasonography can be easily moved and display actual moving structures unlike computed tomography (CT) or magnetic resonance imaging (MRI). Therefore, it is advantageous to the interventional treatment of a critical illness or immediately after surgery. However, since it is difficult to observe the deep structures, and impossible to observe the structures beyond the hard tissue by ultrasonography, its diagnostic image has been used to examine the condition of various structures such as lymph nodes, post-edema, hematoma, eyes, thyroid, parotid, submandibular and sublingual glands.[3] However, this use of ultrasonography is far from the actual treatments performed by most dentists.

Ultrasound diagnosis has been used very actively in the medical field up to the present since it has no radiation dose unlike the other conventional radiodiagnoses, can diagnose the soft tissue diseases, and is possible to diagnose dynamically through the probe movement. The main reason why ultrasound diagnosis has not been applied to the dental field, while it has been used in all fields of medicine, is that a probe for the dental field has not been developed and no suitable indication has been found.

In the past, free gingival graft has been commonly used to cover the exposed root surface caused by the gingival retraction. Also, it was performed to improve the shape of gingival margin of the aesthetic area such as anterior region, and to expand the keratinized gingival area to support removable denture base. Recently, according to the popularization of dental implants, many free keratinized gingival grafts have been performed around the implant prosthesis for easier management by sealing of keratinized gingiva and the plaque control.

A few previous studies reported that the keratinized gingiva around the implants is not helpful in the plaque management or the prevention of bacterial incorporation, [4] however, the practitioners tend to prefer implants surrounded by keratinized gingiva based on their clinical experiences. The most frequent parts to receive free keratinized gingival grafts accompanied with implants are the aesthetic prosthesis area of maxillary anterior and the mandibular posterior. The maxillary anterior already has keratinized gingiva, but the graft is performed to improve aesthetics such as the thickness and width, while the mandibular posterior is performed to obtain the actual gingiva since the alveolar ridge is narrow and the keratinized gingiva is not enough in this area. The preference of the donor site to provide keratinized gingiva is in the order of the maxillary palate, maxillary nodule, and mandibular posterior.

The most important part of the free keratinized gingival graft is how well the gingiva is engrafted. This requires fast treatment and sutures without dead space.[5] Therefore, there are significant differences among the results depending on the proficiency of the operators, and it is difficult to predict the prognosis since the absorption of the implanted free gingiva is frequently observed. Accordingly, it is recommended to transplant more than 30-60% of the required keratinized gingiva. The maxillary palate is a good donor site to collect the large amount of keratinized gingiva required for this, but it is necessary to exercise caution, as there is the greater palatine artery emerging from the greater palatine foramen.

In the past, since the dental clinics were not equipped with the devices to observe the soft tissues and arteriovenous veins, and those devices were limited to expensive equipment such as CT, MRI, and PET. Mia-Michaela Beetge et al reported in their study using micro CT that the greater palatine foramen is located at 12.7 mm from the molar plane. [6] Many studies have reported the location of the greater palatine foramen using CT and radiographic imaging. [7,8] However, radiographic studies are not suitable for detecting the course of the greater palatine artery. Therefore, the only way to localize the course of the arteries was to depend on the anatomical average or the operator's experience.

The greater palatine foramen is usually located at the middle or posterior part of the second molar area. Joe Iwanaga et al marked the foveola palatine as a standard for distance measurement in their study and reported that the greater palatine foramen was located at an average distance of 4.7 mm to 4.8 mm from it. [9] According to Sebastian et al. The greater palatine artery arises from here and travels forward along the palatal vault, and it is known to be located on an average of 8 to 12 mm above the gingival margin of the molar. Brion et al reported in a cadaver study that the height of GM-GPA was 11.9 mm on average and the palatal height was 15.8 mm and that the GPA runs around 76% of the palatal height [4]. Kwang-Hee Cho et al reported that the height of the greater palatine artery as 10.25 mm on average and the depth of it as 4.31 mm through histological assessment.[10]

It is necessary to exercise caution since the course of the greater palatine artery may be mutated or branched, a large amount of bleeding may occur if it is damaged.

Among the various studies to define the accurate anatomical course of the greater palatine artery, the studies using cadavers and CT have been actively conducted, and a systematic literature review of those studies has recently been reported. Tavelli et al. [5] reported that the greater palatine foramen was located, in 57.1% of the cases at the 3rd molar area, 21.3% in the middle of the 2nd and 3rd molar area, and 13.5% at the distal side of the third molar area. The greater palatine artery located at 13.9 ± 1.0 mm from the GM of the second molar, 13.0 ± 2.4 mm from the GM of the first molar, 13.8 ± 2.1 mm from the GM of the second premolar, and 11.8 ± 2.2 mm from the GM of the first premolar. The diameter of the greater palatine artery was reported to be 1.2 ± 0.3 mm in the first molar area.

However, there is a question of its reliability to the studies reported so far have been conducted on a small-scale in the case of cadavers. Many studies have not reported race, gender, age, and height, thus, the representativeness of estimation is poor [11]. Besides, the study of cadavers needs to consider the method of preservation of cadavers, contraction over time, and the possibility of displacement during exfoliation. In studies using CT [12,13], it is relatively free from the aforementioned limitations, but as these studies reported so far have been conducted without contrast-enhanced CBCT, it is not possible to estimate the location of GPA.

In order to overcome the above limitations, this study was conducted to identify the course of normal person's greater palatal artery using diagnostic ultrasound. Its specific purposes are as follows.

1) To measure the distance from the GPA to the Gingival margin of maxillary molar and premolar using Ultrasonography

2) To establish the thickness of the palatal mucosa overlying the GPA using Ultrasonography

3) To investigate the association between GPA anatomy and demographic characteristics including sex and height, arch form

4) Reliability analysis of the ultrasonography measurement by analyzing inter-examiner agreement.

Ⅱ. MATERIALS & METHODS

2.1. Study setting and Participants

This study was conducted on patients who visited the Department of Advanced General Dentistry of Yonsei University Dental Hospital from February 22, 2018 to February 21, 2019. This study was approved by the Institutional review board of Yonsei University Dental Hospital (IRB No. 2-2017-0066).

Individuals who are 20 years or above, not having any history of significant dental ailments were considered for the enrollment, after a voluntary consent. While the individuals with a history of dental problems, an ongoing orthodontic treatment, a tooth extraction, agitated tooth due to severe periodontitis, or a moderate issue case of tooth crowding, as well as any unforeseen disease or accidents to enrollee prompting the researchers difficult to continue, or the cases in which, an enrollee had trouble following the researcher’s instructions were excluded from the study.

2.2. Sample size estimation

The sample size was calculated based on the result of the study of Monnet-Corti V et al., by using G-Power 3.1, and the effect size = 0.5, significance = 0.05, power = 90%, based on the figures for men and women in the 'height of the maxillary premolar & molar area'.

The initial target sample count was calculated to be 38, and the final study subject was calculated to be 40 considering the dropout rate of 5%.

2.3. Instrumentation

The ultrasound images used in this study were taken by Ultrasound scanner (Ecube 9 diamond®, Alpinion Medical System, Seoul, Korea) and the oral probe developed for dentistry, linear Probe (IO3-12®, Alpinion Medical System, Seoul, Korea) (Figure 1).

Figure 1. Image of ultrasound probe: Ultrasound scanner (Ecube 9 diamond®, Alpinion Medical System, Seoul, Korea), Probe (IO3-12®, Alpinion Medical System, Seoul, Korea)

2.4. Outcome measurements

2.4.1. Demographics

Demographic characteristics including age, gender, and height of enrolled participants, who visited the department and met the selection criteria, were investigated.

2.4.2. Measurement protocol

The images were acquired in the following sequence: The subjects were taken to a quiet room, guided into a supine position. After fitting the transducer to their palate, it was measured in the order of #17, 16, 15, 14, 24, 25, 26, 27 starting from the right maxillary second molar. The measurement was performed by 2 dentists, the primary tester measured, the secondary tester immediately recorded the measurement, and it was recorded to the first decimal place (Figure 2).

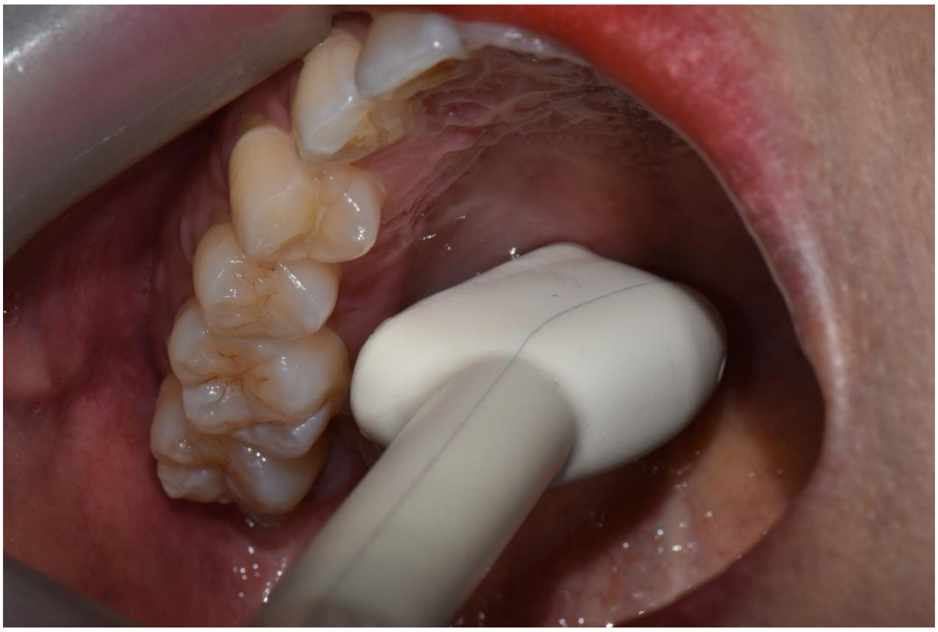


Figure 2. Actual application of ultrasonographic probe for the measurement

2.4.3. Measurement of the distance between the Gingival margin and the greater palatine artery (GM-GPA)

Based on the center of the mesiodistal width of each tooth and the most apical point of the gingival margin, the probe was fitted in the vertical direction to the occlusal plane along the axis of each tooth, and the vertical distance was measured by detecting the artery using the Doppler mode (Figure 3, 4, 5).

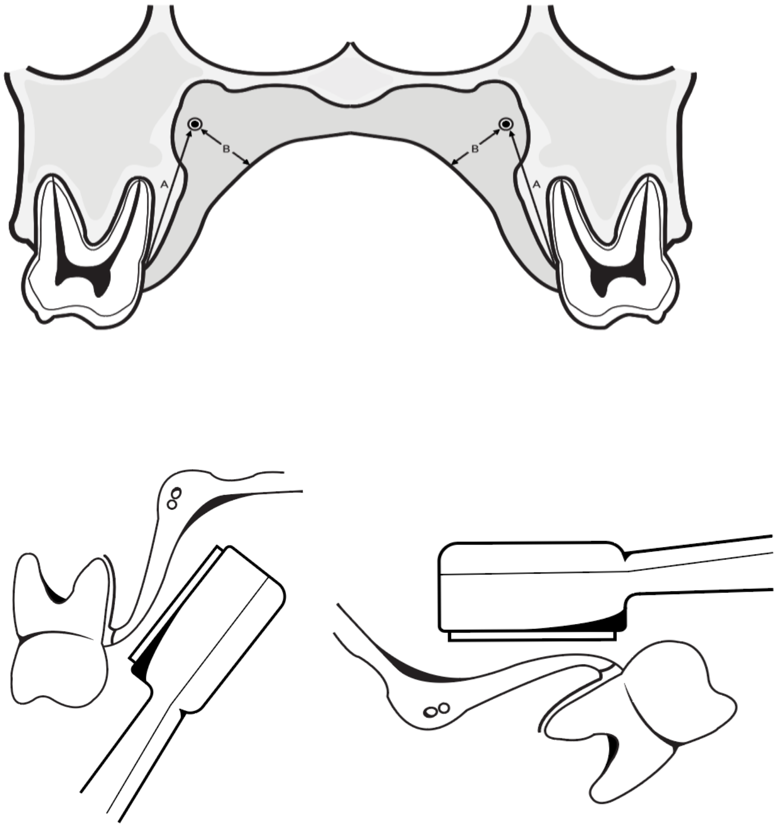
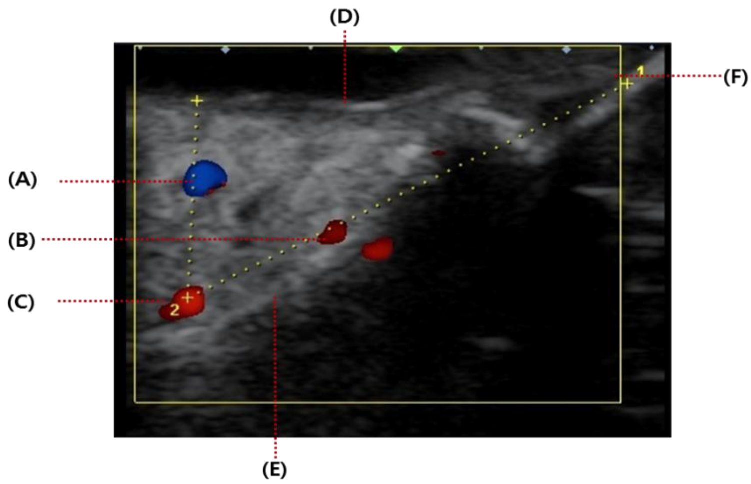


Figure 3. Actual application of ultrasonographic probe for the measurement and Schematic diagram of reference points and measurements in length.

2.4.4. Measurement of the distance from palatal gingiva to the greater palatine artery (PG-GPA)

The horizontal distance from the detected greater palatine artery to the nearest gingival was measured by using the Doppler mode (Figure 3, 4, 5).



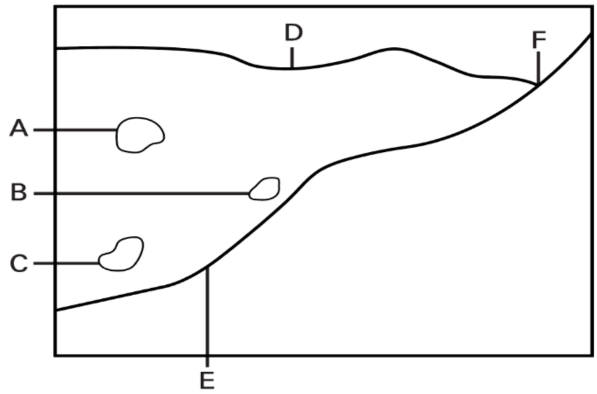


Figure 4. Anatomical structure of GPA in ultrasound image. (A) Greater palatine vein, (B) artery branch, (C) GPA; Greater palatine artery, (D) Out line of PG(Palate gingiva), (E) out line of palate bone, (F) GM : Gingival margin

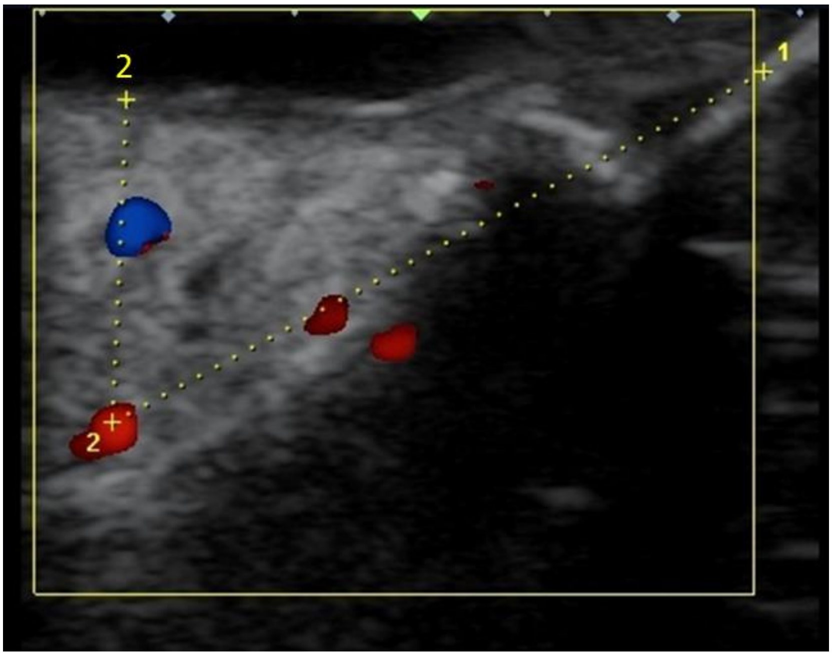


Figure 5. Measuring of Ultrasound image. (1) GM-GPA, (2) PG-GPA

2.4.5. Measurement of the arch with and the palatal height

Before the ultrasound measurement, a dental model was impressed using alginate from each Participant. A custom dental cast was produced using stone and converted into a 3D computer image by a laser dental scanner (T500®, Medit Co., Seoul, Korea). Subsequently, (A) palatal width between palatal cusp tip of left & right first molar (PW6) and (B) palatal vertical depth (PVD) from (A) were measured using a 3D imaging program (Real scan®, 3Dii Co., Seoul, Korea) (Figure 6).

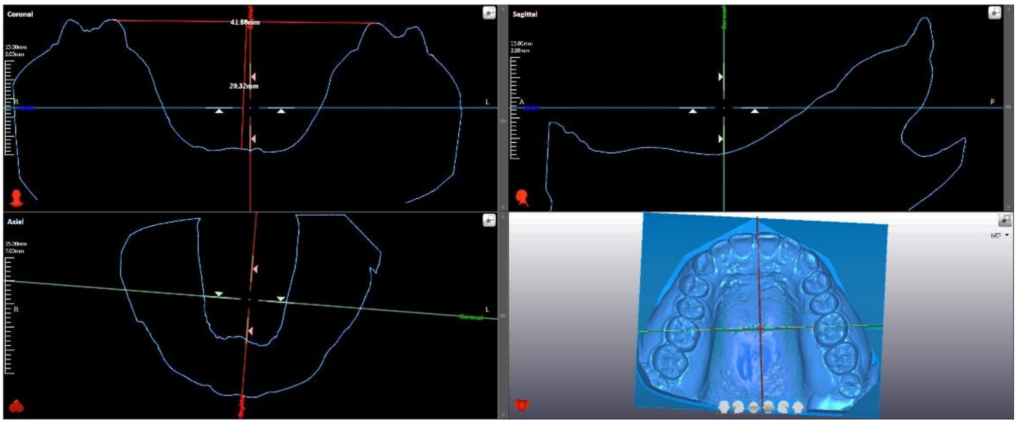


Figure 6. Schematic diagram of reference points and measurements in length on study model 3D computer imaging program (Real scan®, 3Dii Co., Seoul, Korea) (A)PW6; palatal width between palatal cusp tip of left & right first molar (B)PVD; palatal vertical depth

2.5. Statistical Analysis

Measured data was statistically analyzed using IBM SPSS 26.0 (IBM Co., Armonk, NY, USA). Following tests for further investigation were performed: Independent t-tests to investigate differences in measured values for the left and right sides of the mouth and each tooth, ANOVA with Bonferroni correction to investigate differences among age groups, the Spearman rho test to analyze the correlation of the measured values of the ultrasonic image with age and height.

A significant linkage factor analysis was performed through multivariate linear regression analysis. The forward selection method was used for variable selection. To evaluate the inter-examiner reliability, the Bland-Altman plot and ICC(intraclass corelation) analysis were conducted on the individual measurements of the primary tester (Dr. KHL) and the secondary tester (Dr. JEJ).

Ⅲ. RESULTS

3.1. Descriptive statistics

This study screened and enrolled a total of 40 people: 20 males (50%), 20 females (50%) as demographic characteristics, and performed ultrasound measurements on the enrolled participants.

The average age of enrolled participants was 28.85 ± 7.56: 27 (67.5%) people were aged 20-29, 11 (27.5%) people were aged 30-39, and 2 (5%) people were aged 40 and over, and the average height of the participants was 168.28 ± 7.75 cm (Range 155-183).

3.2. Distances between GM (Gingival margin) and GPA (Greater palatine artery)

Among the enrolled participants, the distance of GM-GPA of 20 males was 14.9 ± 1.8 mm, and the GM-GPA of female was 14.24 ± 1.6 mm, therefore, the average GM-GPA of males was larger than that of females ($P < 0.05$). Overall average was 14.8. ± 1.6 mm.

In the right maxilla, the distance of GPA from the cervical margin of each tooth was measured as; 13.85 ± 1.74 mm from the first premolar, 14.38 ± 1.76 mm from the second premolar, 14.59 ± 2.20 mm from the first molar, and 14.93 ± 2.39 mm from the second molar.

In the left maxilla, the distance of GM-GPA was 14.21 ± 2.62 mm from the first premolar, 14.90 ± 2.02 mm from the second premolar, 14.71 ± 1.91 mm from the first molar, and 15.11 ± 2.54 mm from the second premolar.

The mean values on both sides were 14.03 ± 2.22 mm (the first premolar), 14.64 ± 1.90 mm (the second premolar), 14.65 ± 2.05 mm (the first molar), and 15.02 ± 2.45 mm (the second molar). GM-GPA showed differences depending on each tooth (from 1st premolar to 2nd molar), but there was no statistical difference (Table 1, Figure 7, 8, 9).

Table 1. Distances between GM (Gingival margin) and GPA (Greater palatine artery) (mm)

	Total		Male		Female	
	Mean	SD	Mean	SD	Mean	SD
#14	13.85	1.74	14.20	1.88	13.49	1.56
#15	14.38	1.76	14.39	1.47	14.38	2.05
#16	14.59	2.20	14.73	2.41	14.46	2.01
#17	14.93	2.39	15.74	2.49	14.13	2.03
#24	14.21	2.62	14.94	2.83	13.49	2.24
#25	14.90	2.02	15.03	1.92	14.76	2.15
#26	14.71	1.91	15.07	1.60	14.36	2.15
#27	15.11	2.54	15.38	3.10	14.85	1.88
First Premolar*	14.03	2.22	14.57	2.40	13.49	1.90
Second Premolar*	14.64	1.90	14.71	1.72	14.57	2.08
First Molar*	14.65	2.05	14.90	2.03	14.41	2.06
Second Molar*	15.02	2.45	15.56	2.78	14.49	1.96
Total	14.81	1.62	14.93	1.76	14.24	1.58

Results shown are measurements by single examiner (KHL)

* mean estimates of corresponding right and left teeth

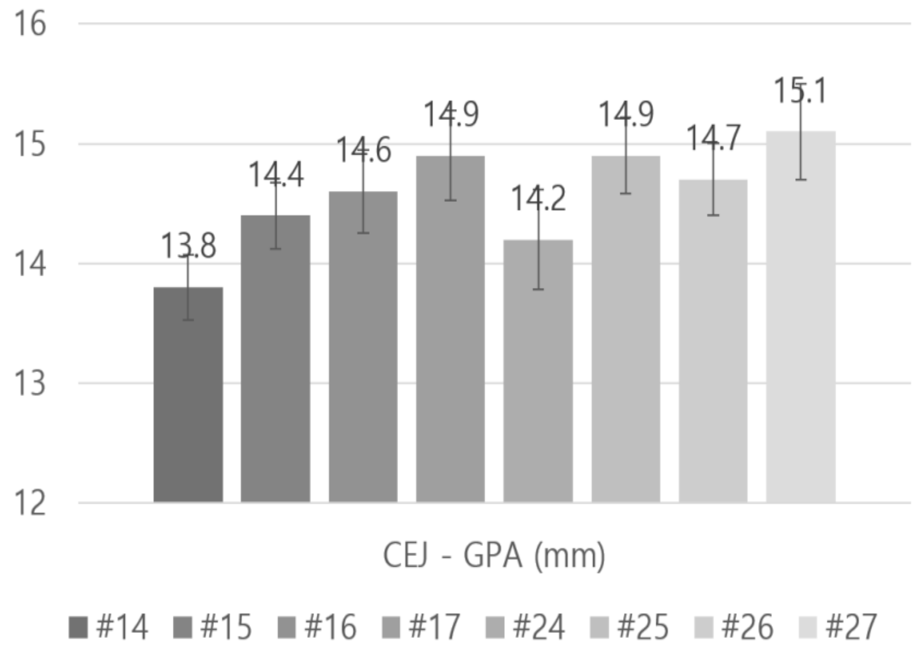


Figure 7. Distances between GM (Gingival margin) and GPA (Greater palatine artery) according to each tooth

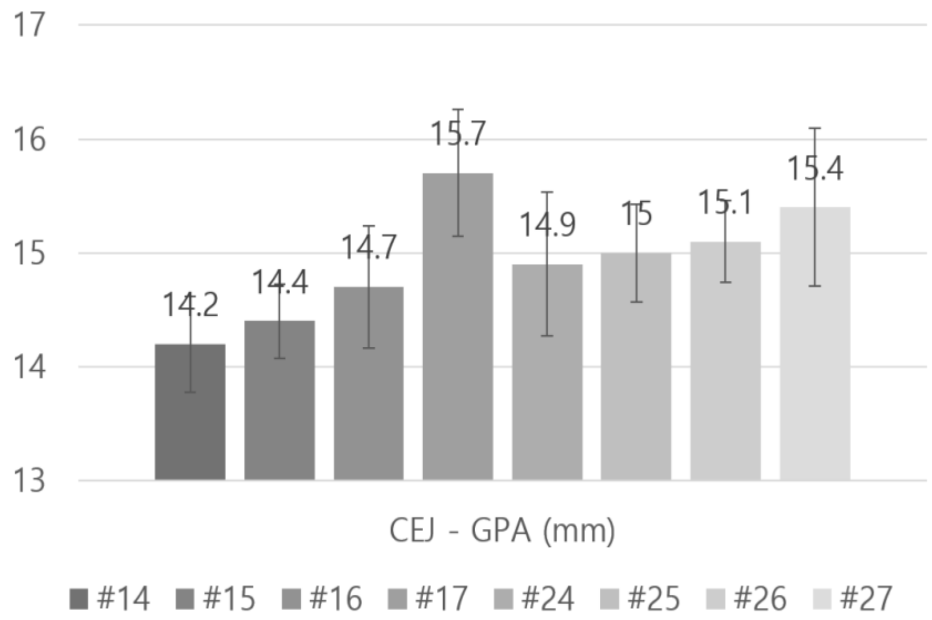


Figure 8. Distances between GM (Gingival margin) and GPA (Greater palatine artery) according to each tooth in men (*n* = 20)

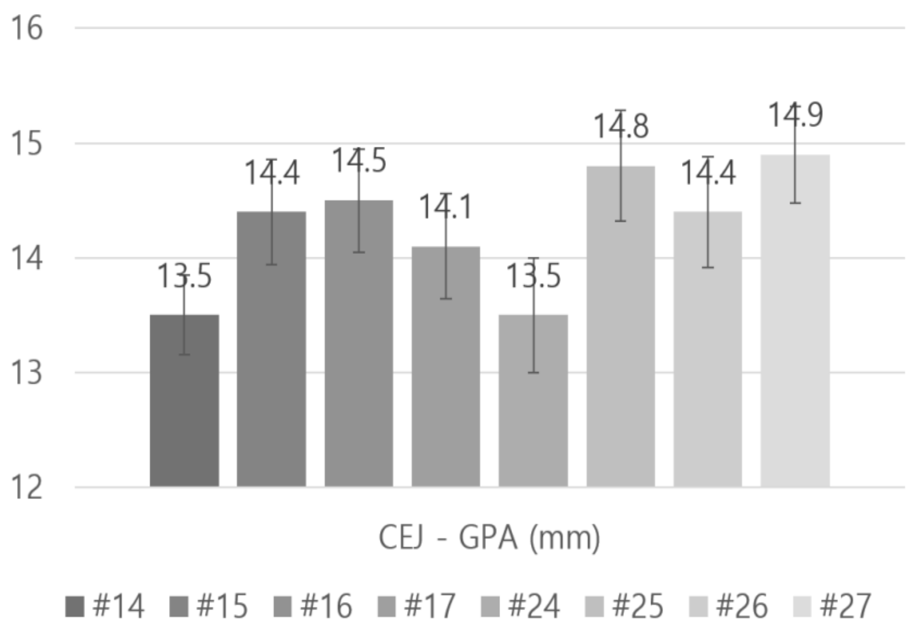


Figure 9. Distances between GM (Gingival margin) and GPA (Greater palatine artery) according to each tooth in women (*n* = 20)

3.2.1. Inter-examiner Agreement for GM-GPA measurement

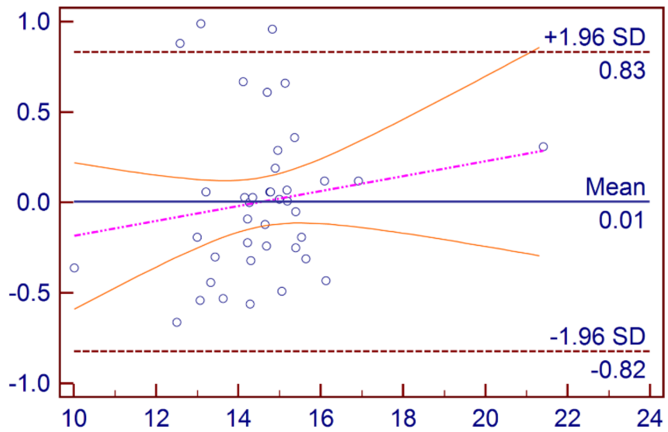
The two examiners performed the GM-GPA measurement at the same time. In the agreement evaluation of the measurements between the two testers, all the teeth except the first premolar (fair) showed high agreement (Excellent; Table 2).

Table 2. Inter-examiner Agreement for GM-GPA measurement

	Total		ICC	95% CI		Agreement
	Mean	SD		Lower	Upper	
First Premolar	14.03	2.22	.789	.602	.889	Fair
Second Premolar	14.64	1.90	.839	.696	.915	Excellent
First Molar	14.65	2.05	.891	.793	.942	Excellent
Second Molar	15.02	2.45	.867	.748	.929	Excellent
Total Measurement	14.59	2.16	.983	.969	.991	Excellent

ICC: intraclass corelation, CI : confidence interval

Altman-Bland plot indicated that the average difference between the two measurements was as low as 0.01 mm. Outliers out of 2 SD (0.83 mm) were found in 3 out of 40 participants (Figure 10) in the Altman-Bland plot analysis. In conclusion, the inter-measurement variance of ultrasonic measurement of GM-GPA was not high.



SD : standard deviation

Figure 10. Altman-Bland plot of ICC (GM-GPA)

3.3. Distances between PG (Palatal gingiva) and GPA (Greater palatine artery)

The average PG-GPA (the horizontal depth of the greater palatine artery) of 40 Korean adults was 4.10 ± 0.51 mm, and there was no gender difference by ($P < 0.05$). The distances of PG-GPA was 2.74 ± 0.69 mm at the 1st premolar of the right maxilla, 3.05 ± 0.77 mm at the second premolar, 4.74 ± 1.26 mm at the first molar, and 5.88 ± 1.51 mm at the second molar.

Horizontal depth of the GPA increased as it moves from anterior to posterior teeth at both sides (Table 3, Figure 11, 12, 13).

Table 3. Distances between PG (Palatal gingiva) and GPA (Greater palatine artery) (mm)

	Total		Male		Female	
	Mean	SD	Mean	SD	Mean	SD
#14	2.65	.61	2.63	.55	2.67	.67
#15	3.11	.86	3.06	.74	3.16	.98
#16	4.53	1.42	4.74	1.40	4.32	1.44
#17	5.79	1.60	5.95	1.70	5.64	1.52
#24	2.84	.76	2.75	.49	2.94	.96
#25	3.00	.68	2.95	.61	3.04	.76
#26	4.95	1.07	5.07	.98	4.83	1.15
#27	5.96	1.42	5.99	1.64	5.93	1.21
First Premolar *	2.74	.69	2.75	.49	2.94	.96
Second Premolar*	3.05	.77	2.95	.61	3.04	.76
First Molar*	4.74	1.26	5.07	.98	4.83	1.15
Second Molar*	5.88	1.51	5.99	1.64	5.93	1.21
Total	4.10	.51	4.14	.52	4.06	.51

Results shown are measurements by single examiner (KHL)

* mean estimates of corresponding right and left teeth

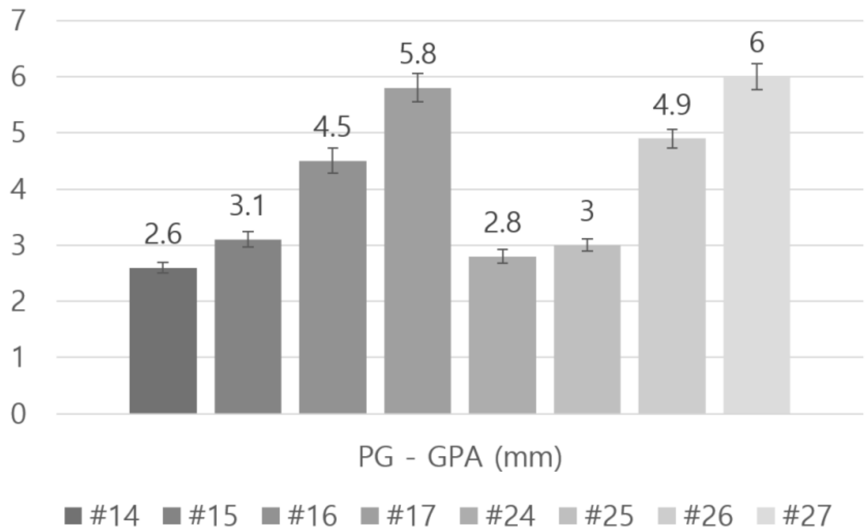


Figure 11. Distances between PG (Palatal gingiva) and GPA (Greater palatine artery) according to each tooth

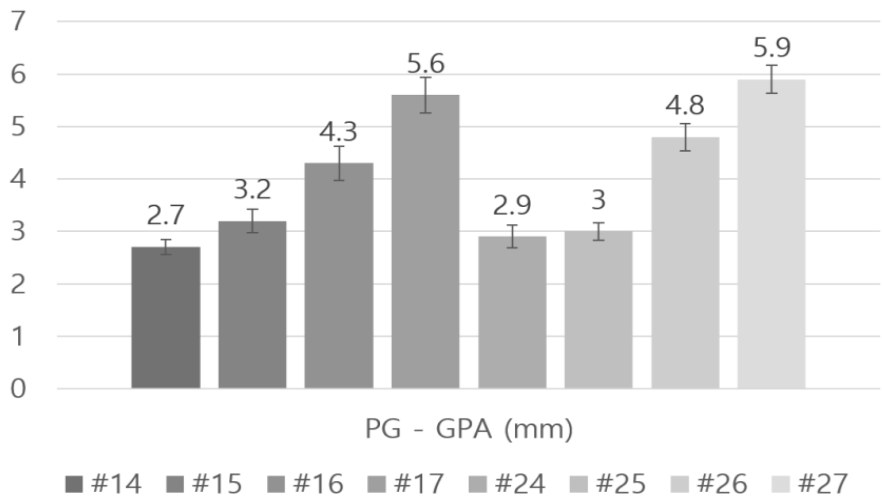


Figure 12. Distances between PG (Palatal gingiva) and GPA (Greater palatine artery) according to each tooth in men (*n* = 20)

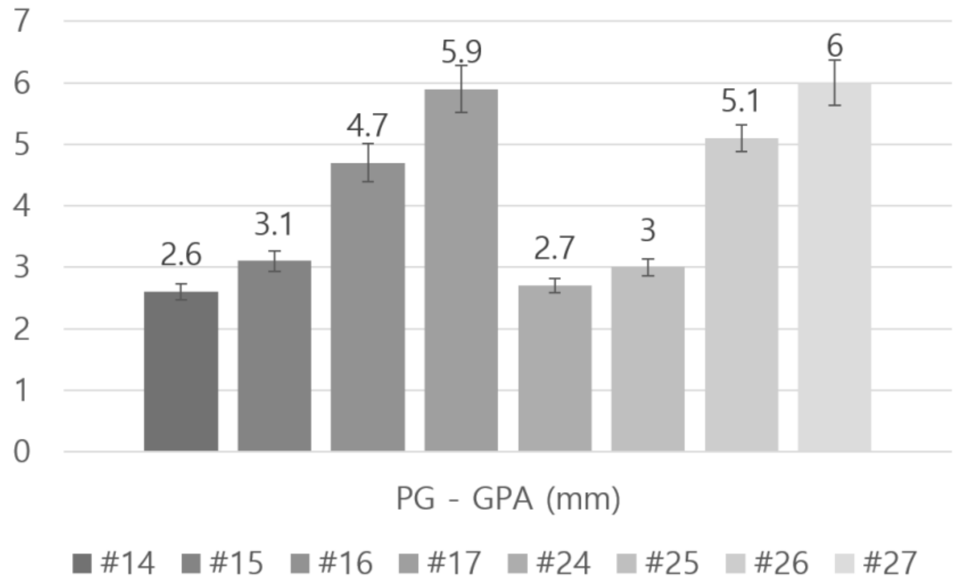


Figure 13. Distances between PG (Palatal gingiva) and GPA (Greater palatine artery) according to each tooth in women (*n* = 20)

3.3.1. Inter-examiner Agreement for PG-GPA measurement

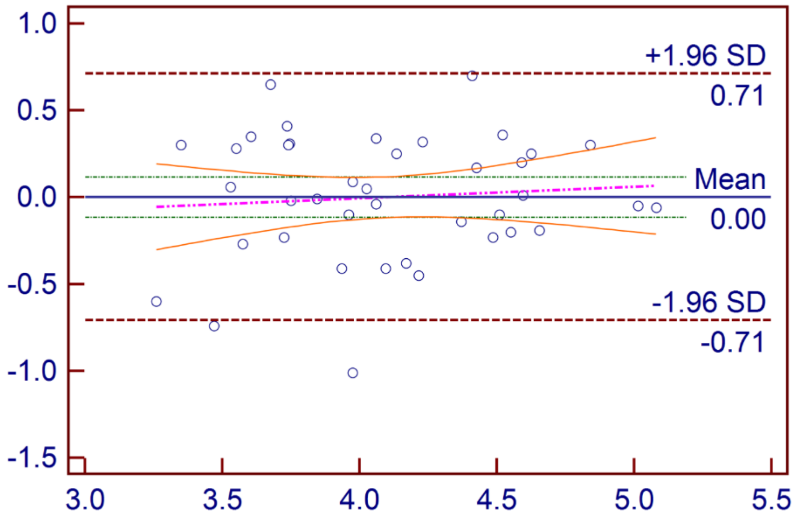
In the agreement evaluation of the measurements between the two examiners, a fair level was shown in all measurements, and a high agreement was shown in the overall measure average. However, it showed a slightly lower agreement compared with that of GM-GPA distance (Table 4).

Table 4. Inter-examiner Agreement for PG-GPA measurement

	Total		ICC	95% CI		Agreement
	Mean	SD		Lower	Upper	
First Premolar	2.74	.69	.636	.312	.807	Fair
Second Premolar	3.05	.77	.720	.470	.852	Fair
First Molar	4.73	1.26	.714	.459	.849	Fair
Second Molar	5.87	1.50	.717	.464	.850	Fair
Total Measurement	4.10	.50	.845	.707	.918	Excellent

ICC: intraclass corelation, CI : confidence interval

Altman-Bland plot analysis indicated that the average difference between the two measurements was as low as 0.00 mm. Outliers out of 2 SD (0.71 mm) were found in 2 out of 40 participants (Figure 14) in the Altman-Bland plot analysis. In conclusion, the inter-measurement deviation of GM-GPA numerical estimation through ultrasonic measurement was not high.



SD : standard deviation

Figure 14. Altman-Bland plot of ICC (PG-GPA)

3.4. Analysis of factors related to distance of GM-GPA

As a result of the correlation analysis, the palatal height was strongly correlated with the human height (Spearman coefficient: 0.395, P <0.05). Also the distance of GM-GPA showed a significant positive correlation with the palatal height (Spearman coefficient: 0.327, P <0.05). In other words, the taller people showed higher palatal height, and people with higher palatal height showed further GM-GPA. Other variables including patients' characteristics and arch width were not significant (Figure 15).

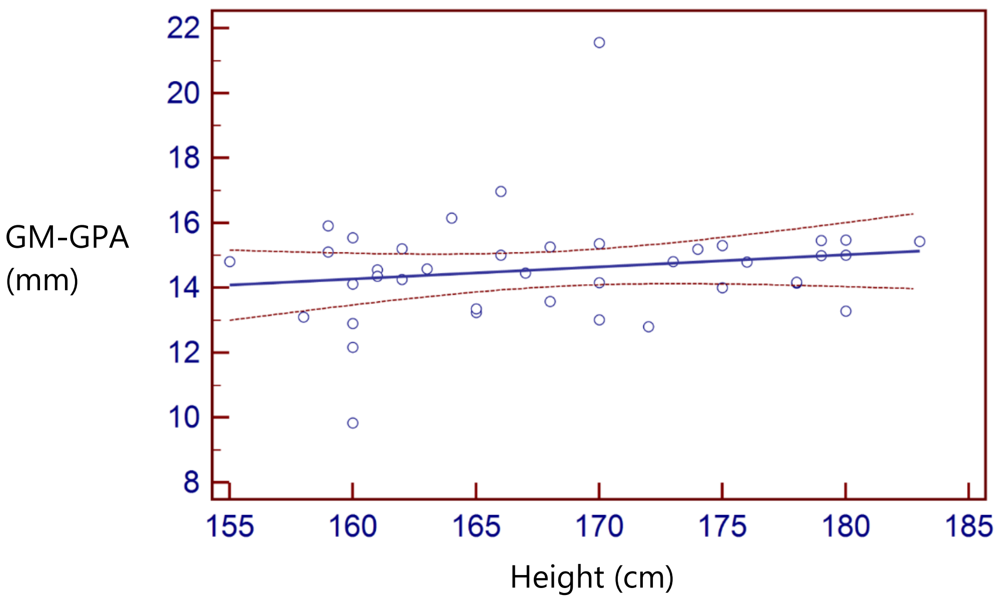


Figure 15. Scatter plot of GM-GPA according to Height. (Spearman coefficient: 0.327, P < 0.05).

As a result of multiple regression analysis, Age, gender, and height were excluded from the final model. Model I indicated arch width was significantly associated with the distance of GM-GPA at both premolar and molar area. Model II indicated that the distance of GM-GPA was significantly associated with arch width and arch height at both premolar and molar area with higher R square value (Table 5).

Table 5. Multiple linear regression analysis for GM-GPA

				95% CI		P
		B	SE	Lower	Upper	
Premolar						
Model I (R:0.347)	Arch Width	0.275	0.057	0.135	0.344	0.000
Model II (R:0.422)	Arch Width	0.278	0.056	0.143	0.346	0.000
	Arch Height	0.176	0.081	0.092	0.384	0.031
Molar						
Model I (R:0.366)	Arch Width	0.275	0.057	0.162	0.388	0.000
Model II (R:0.401)	Arch Width	0.278	0.056	0.167	0.390	0.000
	Arch Height	0.176	0.081	0.016	0.337	0.030

Excluded variables by forward selection: age, sex, height

3.5. Analysis of factors related to PG-GPA

The distance of PG-GPA did not show a significant correlation with the palatal height or the arch width, or the human height. PG-GPA showed a positive trend with age, but it was not statistically significant (Figure 16).

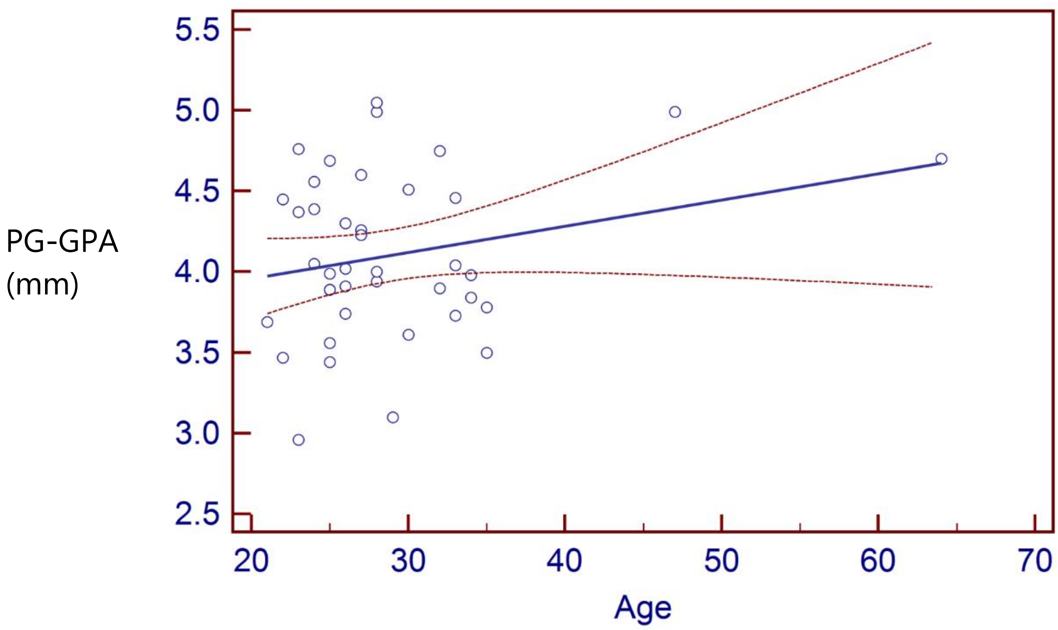


Figure 16. Scatter plot of PG-GPA according to Height. (Spearman coefficient: 0.090, P > 0.05).

As a result of multivariate regression analysis, only age was found to be significantly associated with the distance of PG-GPA at the premolar area. Other model with set of dependent variable as ‘Molar’ and ‘Total’ was not feasible by various variables selection methods (Table 6).

Table 6. Multiple linear regression analysis for PG-GPA

				95% CI		P
		B	SE	Lower	Upper	
Premolar						
Model I (R:0.705)	Age	0.054	0.009	0.035	0.072	0.000

Other model with set of dependent variable as ‘Molar’ and ‘Total’ was not feasible by various variables selection methods.

Ⅳ. DISCUSSION

The greater palatine artery (GPA) originates from the descending palatine artery (DPA), which branches out of the maxillary artery in the pterygopalatine fossa. The DPA descends through the pterygopalatine canal and passes through the greater palatine foramen, which is open downwards and enters the GPA. The GPA runs forward through the sulcus palatine and passes to the incisive foramen to anastomose with the nasopalatine artery. The average diameter of the GPA is reported to be 2.54 ± 1.3 mm in the GPF and 1.96 ± 0.9 mm in the first molar. [14]

The result of the measured distance between GM-GPA in this study was not significantly different from the previous studies using the cadavers. According to Fu et al. [15], the GM-GPA distance of the first molar was 13.1 ± 2.0mm, the first premolar was 12.2 ± 2.0mm, and Benninger et al. [4] reported that the distance of the mesial line angle of the first molar was 11.9 ± 1.8mm. Since these figures are located at 76% of the palatal height, it has been emphasized that the horizontal incision must not exceed 68.5% of the palatal height. The measured value of this study was also 14.8 mm, and the use of ultrasound has a strength that it can be applied immediately during actual clinical surgeries unlike the study results from the cadavers. However, the study of the oral anatomical structure using ultrasound is still lacking. Najmus Sahar Hafeez et al. [16] reported the implementation of the greater palatine nerve block using an ultrasound device. Kang-Hee Lee et al. [17] reported the usage of an ultrasound device to detect the course of the greater palatine artery and employing it on a free gingival graft case. Maria-José Tucunduva et al. [18] measured the blood vessels inside and outside of the oral cavity using a linear transducer.

The posterior palate is very useful for harvesting free gingiva, connective tissue, and full mucosal flap. In addition to the GM-GPA distances described above, several studies have been conducted on the thickness of palatal mucosa. Most studies employed needles, endodontic instruments, periodontal probes, or CT and CBCT. The method of using a periodontal probe is to insert the tip of the probe inside the palatal mucosa to measure the distance from the mucosa to the palatal bone after a local anesthesia, and it was reported that the thickness was around 2.0 – 3.7 mm and that younger and females had thinner thickness than older and males. Overall, it was reported that it becomes thicker as it moves from canine to the 2nd molar (Table 7).[19-26]

Table 7. Reference data of Thickness (mm) of the palatal mucosa (PMC) from the existing studies

Author(s)	Study Material	N	Caine Area	First premolar area	Second premolar area	First molar area	Second molar area	Comments
Studer et al. [19]	31 Caucasian patients (bone sounding with periodontal probe) (mean age 35 years, range 21-52 years)	3 1	At 3mm : 2.6±0.6 At 8mm : 3.2±0.5 At 12mm : 3.3±0.6	At 3mm : 2.4±0.6 At 8mm : 3.2±0.5 At 12mm : 3.9±0.6	At 3mm : 2.5±0.8 At 8mm : 3.2±0.7 At 12mm : 3.8±0.8	At 3mm : 1.8±0.8 At 8mm : 2.2±0.8 At 12mm : 3.5±1.3	At 3mm : 2.6±0.8 At 8mm : 2.7±1.1 At 12mm : 3.5±1.2	PMC was measured at three levels (3, 8, 12 mm) from the gingival margin
Wara-aswapati et al.[20]	62 Asian patients(bone sounding with periodontal probe) (age range 14-59 years)	62	At 3 mm : 2.0±0.5 At quarter line : 2.7±0.6 At half line: 2.4±0.7	At 3 mm : 2.1 ±0.5 At quarter line : 3.1±0.5 At half line : 3.3±0.8	At 3 mm : 2.2±0.6 At quarter line : 3.4±0.7 At half line : 3.5±0.8	At 3 mm : 2.1±0.7 At quarter line : 2.9±0.8 At half line : 4.1±1.1	At 3 mm : 2.7±0.9 At quarter line : 3.8±1.2 At half line : *6.0±1.0	PMC was measured at three from the gingival margin : at 3 mm, at one quarter, and at half of the distance between the 3-mm line and the midsagittal line of the palate.

								*n=31
Song et al.[19]	100 patients(CT) (mean age 45±12 years, range 17-71 years)	200	3.46±0.46(*2.81, 3.61, 3.96, 3.82)	3.66±0.66(*2.77, 3.84, 4.37, 4.54)	3.81±0.75(*2.84, 4.03, 4.57, 4.78)	3.13±0.69(*2.30, 3.08, 4.00, 4.88)	3.39±1.00(*2.29, 3.27,4.62, 6.25)	PMC was measured at four levels(*at 3, 6, 9, 12mm)from the gingival margin
Barriviera et al.([21]	31 patients(CBCT) (mean age 32 years, range 19-53 years)	62	2.92(*1.97, 2.97, 3.48, 3.29)	3.11(*2.07, 2.90, 3.55, 3.93)	3.28(*2.12, 2.95. 3.85, 4.22)	2.89(*2.11, 2.34, 2.92, 4.21)	3.15(*2.22, 2.28, 3.08, 5.02)	PMC was measured at four levels(*at 2, 5, 8, 12 mm from the gingival margin). Statistical differences were observed at different ages and heights of measurements
Schacher et al.[22]	33 patients(bone sounding with cannulas) (mean age 27.8±4.1	33	Males : 4.62±1.08 Females : 5.45±0.96	Males : 5.06±0.78 Females : 5.10±0.73	Males : 5.03±0.74 Females : 5.25±0.87	Males : 3.76±0.56 Females : 4.84±1.13	Males : 4.89±1.94 Females : 6.44±1.40	Unilateral measurements were taken 8 mm from gingival margin using a

	years, range 23-41 years)							template: Significant differences
Ueno et al.[23]	5 cadaveric heads(CT)	10	*Anterior area : Dentate : 3.54±0.90 Edentulous : 3.02±0.92			**Posterior area: Dentate: 2.83±1.28 Edentulous: 3.03±0.98		*Incisor and canine area **Premolar and molar area
	5 cadaveric heads(bone sounding with reamers)	10	*Anterior area : Dentate: 3.33±0.75 Edentulous: 3.10±0.89			**Posterior area: Dentate: 2.62±1.20 Edentulous: 3.13±0.79		
Marquezan et al.[24]	36 patients (CBCT) (mean age 23.6±11.9 years)	36		*4 mm midline : 2.92±.1.27 at 3 mm : 3.38±1.03 at 6 mm : 5.33±1.59	*8 mm midline : 2.06±0.95 at 3 mm : 2.83±0.83 at 6 mm : 3.98±1.16	*16 mm midline : 1.53±0.7 at 3 mm : 2.04±0.83 at 6 mm : 2.86±0.87	*24 mm midline : 1.33±0.59 at 3 mm : 1.75±0.58 at 6 mm 2.54±0.73	Measurements were taken at 4, 8, 16, 24 mm behind the incisive foramen(roughly corresponding to the first and second premolar and molar

								sites) in the midline and at 3 and 6 mm lateral to the midline
Kim et al. [25]	22 Korean cadavers	43	2.8±1.1 mm	3.2±1.1 mm	3.2±1.2 mm	3.1±1.6 mm	3.5±2.1 mm	Measurements were taken at four different levels from the gingival margin
Yilmaz et al. [26]	345 Turkish patients (CBCT) (mean age 40.6 years, range 15-69 years)	345	3.0±0.63 range of means : 2.1-3.9	3.0±0.75 range of means : 2.2-3.8	3.7±0.61 range of means : 2.3-5.1	3.3±0.74 range of means : 2.3-4.7	3.7±0.48 range of means : 2.2-5.5	Measurements were taken at three levels(corocoro, middle, apical)

As a result of the regression analysis, the variables that showed a significant correlation with GM-GPA were the width and height of the dental arch. Age, gender, or height did not show statistical significance. Therefore, in actual clinical practices, GM-GPA can be predicted through the patient's facial profile and the shape of the arch.

On the other hand, the variable related to PG-GPA was gender. This is thought to be related to the degeneration and increased amount of salivary glands and adipose tissues in the palate, with increasing age.

The result of the analysis through the Altman-Bland plot reported that the average difference between the two testers was very low. By this, it can be concluded that the inter-measurement deviation of GM-GPA and PG-GPA numerical estimation through ultrasonic measurement is not high. Nevertheless, the measurement through the ultrasound imaging holds the possibility of error.

Measurement errors usually occur when the operator puts the probe in the wrong direction or position. If the probe is not parallel to the tooth axis and tilted forward or backward (GM-GPA) or rotated along the axial (GM-GPA), the measured value will be larger than the actual value due to image distortion (Figure 17). Improper position and orientation of these probes are caused by limitations in intraoral vision, interference of the oral angle, or difficulties in accessing the probe due to the palatal shape. Or, it may be caused by a simple mistake of the operator or a movement of the patient. When there are branches in the greater palatine artery, the main branch can be judged differently depending on the operator, which also causes measurement errors.

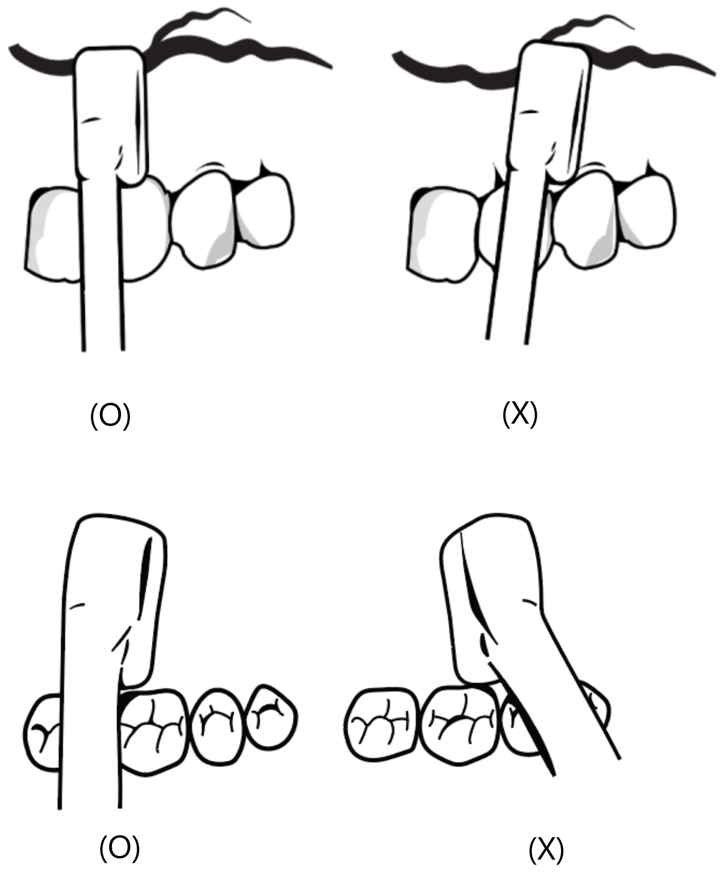


Figure 17. Possible measurement errors. The measuring probe should be positioned horizontally on the long axis of the tooth and perpendicular to the

occlusal surface, otherwise a measurement error will occur.

Diagnostic ultrasound device has been widely used in the medical field. However, its use has been limited in the dental field. Ultrasound is a relatively safe and effective tool for evaluating and diagnosing various soft tissue diseases in the head and neck site.

To date, computed tomography (CT), magnetic resonance imaging (MRI), proton emission tomography (PET), and combinations of these have been widely used to examine and diagnose the maxillofacial abscess, soft tissue benign or malignant tumor, or lymphatic metastasis of malignant tumor. MRI can be effectively used to diagnose soft tissue lesions, such as the parotid gland and the mandibular gland, but it is not easily accessible for general clinicians since the equipment is expensive and takes up significant space. Compared to this method, the diagnostic ultrasound has the advantages of non-invasive, low cost, and no radiation exposure. Also, the equipment takes up little space and the inspection time is relatively short.

'Doppler mode' is a mode that employs Doppler effect. Doppler effect means ‘the frequency of the sound emitted by a moving object causes a change’.

As the boundary of the medium (reflector) moves toward the sound source, the frequency it reflects becomes higher than the incident frequency when it approaches closer, and it becomes lower than the incident frequency when it moves away. As the speed of the interface increases, the difference between the incident and reflected frequencies (Doppler shift) increases. Measuring the Doppler shift of blood cells moving inside a blood vessel makes it possible to measure the vascular patency, presence of stenosis, and the speed and amount of blood flow. In this mode, it has an option to mark the fluid flows in red and blue according to the direction they flow, and this allows finding the location of the carotid artery, the coccal vein, and the facial artery more effectively.

To avoid the palatine nerves and arteries in conventional surgical procedures, depending on the anatomical knowledge was the most common way. The greater palatine foramen is located at the middle or posterior area of the second molar according to Sebastian et al. The greater palatine artery, which originates from here, runs forward along the palatal vault, and it is reported that it travels on an average of 8 to 12 mm above the gingival margin of the molar. However, since the arterial blood vessels have many variations and often produce unexpected thick branches, unexpected bleeding problems during palatal minor surgery can occur. Using ultrasound makes it possible to check the course of the greater palatine artery more clearly, which is essential for safe surgery.

In addition, ultrasound can measure the gingival thickness of various sites, which is useful in determining the donor site. The gingival thickness of the recipient site may be measured and considered in determining the donor site.

In previous studies, it was conducted to measure the gingival thickness of each site for mini screw placement, however, those previous studies measured the probe with cadaver gingiva rather than living tissue, therefore, there was some deformation and error as much as the moisture was lost after death. Additionally, it causes invasive and repeated pain and fear, which is difficult to perform on the live patients. Ultrasound can measure the gingival thickness of each site free from radiation, regardless of the frequency and time.

This is useful when performing various gingival surgeries or the second stage of implant surgery. Measurement is possible before, during, and after surgery.

There have been studies to measure the thickness of the gingiva through CT images (Song et al. 2008. J periodontal), [19] but the women of childbearing age and with the possibility of being pregnant are reluctant to undergo CT scans. Ultrasound can be taken regardless of whether they are pregnant or not, therefore, it is a more comfortable option for both the patient and the operator.

In conclusion, ultrasonography is far superior to general radiographs in examining soft tissues, has no side effects, and has no biological adverse effects. In particular, ultrasound is very useful for observing the surface of soft tissue rather than the deep part and is very useful for observing the condition and size of inflammation, and the location of blood vessels. Recently, the price reduction of ultrasound imaging equipment has opened the possibility of popularization in the dental industry. Various dental applications utilizing this should be explored.

Ⅴ. CONCLUSION

In this study, the courses of the greater palatine artery of normal people were identified by using diagnostic ultrasound (Ecube 9 diamond®, Alpinion Medical System, Seoul, Korea) to overcome the limitations of the existing studies, and the following conclusions were obtained.

1. The vertical height (GM – GPA; Distance from the gingival margin to the greater palatine artery) of the palatal artery of Korean adults was 14.8 ± 1.6 mm. GM-GPA of male was 14.9 ± 1.8 mm, which was significantly larger than that of female (14.24 ± 1.6 mm; $P < 0.05$).

2. GM-GPA showed differences according to teeth (from the first premolar to the second molar), but there was no statistical significance.

3. The average PG-GPA (depth of the greater palatine artery) of 40 Korean adults was 4.10 ± 0.51 mm, and there was no gender difference.

4. Depending on the teeth (from the first premolar to the second molar), gingival thickness was observed to increase toward the posterior.

5. Inter-examiner agreement for the measurement of both GM-GPA and PG-GPA presented excellent agreement. Each ICC value was 0.983 (0.969-0.991) and 0.845 (0.707-0.918), respectively.

6. Palatal height was strongly correlated with the human height and GM-GPA (Spearman coefficient: 0.395, 0.327; $P < 0.05$).

7. Multiple regression analysis indicated that arch height and arch width were significantly associated with the GM-GPA

8. The distance of PG-GPA did not show a significant correlation with the palatal height or the arch width, or the human height.

9. Multiple regression analysis indicated that only age was found to be significantly associated with the distance of PG-GPA at the premolar area.

This study suggests the directions to utilize the dental probes in various ways and to increase the use of ultrasound in the dental field. Evaluating the oral soft tissues in a non-invasive manner is expected to contribute to safer and more assertive surgeries by reducing the patient’s discomfort, the possibility of accidents during surgery, and complications after surgery.

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국문요약

초음파영상 진단장비를 이용한

대구개동맥 주행의 추적

초음파 진단법은 기존의 방사선 진단법에 비해 방사선 조사량이 없으며, 연조직 질환의 진단이 가능하며, 프루브의 움직임을 통한 동적 진단이 가능하기 때문에 의학분야에서 매우 활발히 사용되어 왔다. 많은 의학 분야에서 사용되고 있는 초음파 진단이 치과 분야에 적용되지 못한 가장 주된 이유는 치과분야에 맞는 프루브가 개발되지 않았던 점과 적절한 적응증을 찾지 못하였기 때문이다.

상악 구개부는 유치치은이식술, 결체조직이식술 등에 사용되는 다량의 각화치은을 채취하기 좋은 공여부이지만 대구개공에서 시작되어 전방으로 주행하는 대구개 동맥이 있어 주의하여야 한다. 대구개공은 보통 제 2 대구치의 중간이나 후방위치 상방에 존재한다. 여기서 주행을 시작하는 대구개 동맥은 palatal vault 를 따라 전방으로 나아가는데 대구치 치은 변연에서 평균적으로 8~12mm 상방으로 주행한다고 보고된다. 과거 치과에서는 연조직, 동맥, 정맥 등을 관찰하기 위한 기기가 없었고 그

외의 관측 장비도 CT, MRI, PET 등 고가의 장비에 한정되어 있었으므로 동맥의 주행은 해부학적인 평균치나 술자의 경험에 의존할 수밖에 없었다. 대구개동맥의 주행은 변이가 있거나 가지를 내는 경우가 있는데 이를 손상시키면 다량의 출혈이 일어날 수 있어 주의가 요구된다.

치과 방사선 영상 진단법은 지금까지 치의학 진단에 매우 중요한 역할을 수행하여 왔다. 그러나 방사선 영상 진단은 방사선 조사를 피할 수 없으며, 대부분의 방사선 영상은 정지영상이므로 동적인 움직임을 평가하는 것이 불가능하고, 특히 연조직 질환의 평가가 불가능하다는 한계가 있다. 또한 사체를 이용한 해부구조의 측정은 조직의 수축에 의한 오차가 발생한다. 탐침에 의한 측정 방법은 침습적이고 환자에게 통증을 유발하며 술자의 숙련도에 따라 측정 오차가 발생할 수 있다.

이러한 기존 연구의 한계점을 극복하고자 본 연구에서는 초음파영상 진단장비(E-cube 9; Alpinion Inc., Seoul, Korea) 및 구강 전용 프로브를 이용하여 한국 정상 성인에서 (N=40, 20-59 세) 상악 구개부의 동맥 주행을 추적하였으며, 다음과 같은 결과를 얻었다.

1. 한국인 성인의 대구개동맥의 수직적 높이 (GM-GPA; Distance from gingival margin to greater palatine artery)는 14.8 ± 1.6mm 였으며 남성 (N=20)의 수치가 14.9 ± 1.8mm 로 여성 (N=20)의 14.24 ± 1.6mm 보다 유의하게 컸다.

2. 치아에 따라(제 1 소구치 ~ 제 2 대구치) GM-GPA 가 차이를 보였지만 유의성은 없었다.

3. 한국인 성인 40 명의 PG-GPA(대구개동맥의 깊이)는 4.10mm 로 남성이 여성보다 치은이 두꺼웠다.

4. 치아에 따라(제 1 소구치 ~ 제 2 대구치) 후방으로 갈수록 치은 두께가 증가하는 양상이 관찰되었다.

5. 동일 환자에서 측정자 1,2 간에 측정값은 유의성 있는 유사성을 보였다.

6. 악궁의 수직적인 높이와 대구개 동맥의 주행 높이는 강한 상관성을 나타냈다($p<0.05$)

7. 다중회귀분석에서 악궁의 수직적인 높이와 수평적인 넓이는 대구개 동맥의 주행 높이와 상관성이 있었다.

8. 악궁의 수직적인 높이와 수평적인 넓이, 그리고 키는 치은 두께와는 상관성이 없었다.

9. 다중회귀분석 결과, 나이만 치은의 두께와 상관성을 나타내었다.

결론적으로 치조골연에서부터 대구개 동맥의 두께와 높이는 남성에서 더 크게 관찰되었다. 대구개 동맥의 주행 높이는 구개의 높이와 연관성이 있었다. 측정자 간의 계측값은 유사성을 보였다.

본 연구를 통해 치과용 초음파 프루브의 활용 방안을 찾고 치과 영역에서 초음파의 활용 방안을 늘려갈 방향을 제시할 수 있다. 또 비침습적인 방법으로 구강연조직을 평가함으로써 환자의 불편감을 줄이고, 술 중 생기는 사고발생 가능성을 줄이고 합병증을 예방함으로써 술자가 보다 안전하고 적극적인 수술을 진행할 수 있도록 도와줄 수 있으리라 기대된다.

핵심되는 말: 초음파상, 대구개동맥, 대구개신경 주행, 구개, 치은 두께