The Surgical Anatomy of the Greater Palatine Artery: A Human Cadaver Study

Identifying the accurate location of the greater palatine artery (GPA) can be challenging. The purpose of the present cadaver study was to determine the location of the GPA from the cementoenamel junction (CEJ) of the maxillary canine to second molar teeth and to define its relationship with the palatal vault height (PVH) in Caucasian cadavers. Sixty-six sections from fully or partially dentate cadavers were examined. The location of the GPA from the CEJ ranged from a minimum of 8.7 ± 2.1 mm at the canine to 14.5 ± 1.3 mm at the second molar. The minimum distance of the GPA to the CEJ in different PVH ranged from 6 to 12 mm. There was a significant difference between male and female cadavers regarding shallow PVH. Only the PVH as an independent variable had a significant correlation with the GPA location. The present study is the first to identify the different PVHs with customized stents and to correlate them with the distance of the GPA to the CEJ of maxillary teeth. Int J Periodontics Restorative Dent 2022;42:233–241. doi: 10.11607/prd.4945

Since the 1960s, clinicians have used autogenous soft tissue grafts to correct mucogingival deformities such as gingival tissue thickness, gingival recession, and lack of keratinized tissue. The subepithelial connective tissue graft (SCTG) was first described by Langer and Calagna and was initially indicated for ridge contour alterations for aesthetic compromises in prosthetic restorations. In 1985, Langer and Langer, due to the limited success of the coronally repositioned flap, introduced the SCTG to gain total root coverage in single and multiple recession sites. The palate from the distal canine region to the second molar is recommended as a potential donor site, as this region allows the harvesting of a sufficient amount of a SCTG due to the presence of a uniformly thick mucosa. SCTG harvested from the palate or the maxillary tuberosity has been the graft of choice for mucogingival procedures because of the good color match, ability to be left exposed 0.5 to 1 mm, and root coverage ability. SCTG harvested from the hard palate has been shown to achieve a mean root coverage close to 98% of the defect. A downside to this procedure is that the amount of

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connective tissue that can be harvested may be limited by the patient’s anatomy and the associated discomfort from the donor site.10

Several techniques have been described for harvesting SCTG from the palate.3,4,9–15 In 1974, Edel used a trap door approach to harvest the graft without removing the epithelium from the donor site, allowing for healing by primary intention.11 In 1980, Langer and Calagna harvested the graft with the use of one horizontal and two vertical incisions, allowing for a primary intention healing.3 In 1985, Langer and Langer described a technique using two horizontal and two vertical incisions. The connective tissue and epithelium between the two horizontal incisions were excised and transferred to the recipient site.5 Raetzke introduced a technique in 1985 with two crescent shaped incisions, 1 to 2 mm apart, in an anterior/posterior direction. Then, a wedge of connective tissue was removed along with a small band of epithelium that had to be partially deepithelialized.12 In 1999, Bruno revealed a technique where two horizontal (one perpendicular and one parallel to the long axis of the tooth) and two small vertical incisions were performed. After harvesting the graft, the epithelial band was removed and would be placed underneath the flap.14 In 1999, Hürzeler and Weng presented a single horizontal incision technique parallel to the gingival margin without removing the epithelium (Fig 1).10 Finally, in 2010, Zucchelli et al presented the epithelialized gingival graft harvesting technique. Essentially, it was a free gingival graft where the external surface was deepithelialized, and the donor site was healed by secondary intention.15

The greater palatine neurovascular bundle, which includes the greater palatine artery (GPA), runs through the palatal connective tissue and enters the hard palate through the greater palatine foramen, continuing anteriorly.16 Next, it enters the incisive canal to anastomose with the nasopalatine branch of the sphenopalatine artery.16 If the neurovascular bundle is inadvertently harmed during SCTG harvesting, a surgical complication will occur, like hemorrhage or paresthesia.17 Management of bleeding could be challenging, as it requires direct application of pressure, ligation, or cautery of the artery if the bleeding vessel is visible. If the bleeding vessel is not visible, deep sutures should be placed. Additional hemostatic measures include anesthesia with vasoconstrictors, application of an oxidized cellulose polymer, a clear plastic stent, or an absorbable gelatin sponge.17

Based on the distribution patterns, the GPA has three branches: canine, medial, and lateral.18 Four patterns were described by Yu et al based on the separation of the branches before or after the bony prominence.19 Reiser et al showed a positive correlation between the GPA location and the three different PVH. In addition, they described the location of the neurovascular bundle from the CEJ of the corresponding teeth to be 7 mm in a shallow PVH, 12 mm in an average PVH, and 17 mm in a high PVH.19 However, Reiser et al did not provide values for the

![Fig 1 An SCTG is harvested from the palate using the single incision technique.](image-url)
height of a shallow, average, or high palate vault, and the reported values were based upon a personal communication with G. M. Bowers in 1995. Thus, knowledge of the precise location of the GPA provides a valuable landmark to help avoid surgical complications (Fig 2).

The purpose of the present study was to determine the location of the GPA from the cemento-enamel junction (CEJ) of the maxillary canine to second molar teeth and determine its relationship to the palatal vault height (PVH) in Caucasian cadavers. Knowledge of the position of the GPA and its specific relationship to the PVH is of paramount importance to the clinician when planning SCTG procedures and other periodontal surgeries in the palatal region.

Materials and Methods

A Colorado Multiple Institutional Review Board approval was not required to conduct the study. A total of 35 embalmed fully or partially dentate Caucasian cadavers, donated to the Department of Anatomy, School of Medicine, University of Colorado, were dissected. This study was done in accordance with the Declaration of Helsinki on medical protocols and ethics. The inclusion criteria were as follows: Each quadrant had to have their canine through second molar teeth (specimens with missing first premolars were excluded), and teeth were not supra-erupted or misaligned in the arch. If there were multiple missing teeth or unidentifiable CEJs, the specimens were excluded. The specimens consisted of 16 males (M) and 19 females (F) with an age range of 53 to 98 years (mean age: 75.5 years).

One examiner (L.H.) performed all dissections and measurements. The PVH was measured vertically from the midpalatal suture to the level of the CEJ of the maxillary first molar with the use of a customized stent.
fabricated for each specimen using 0.02 Raintree Essix material (Dentsply Sirona). A UNC-15 probe (Hu-Friedy) was placed in the center of the custom stent to measure the PVH (Fig 3). Categorization of the PVH was as follows: shallow (9 to 11 mm), average (12 to 14 mm), and high (≥ 15 mm). Sectional cuts were made in the palate to visualize the artery and make measurements of the GPA's distance from the CEJ of the corresponding teeth (Fig 4). The distance of the GPA was measured to the nearest millimeter from the midpalatal CEJ region to the GPA, from canine to second molar, using a UNC-15 probe (Fig 5). Whenever possible, a full dissection of the palate was performed to trace the artery and further confirm the measurements (Fig 6). All measurements were calculated to the nearest millimeter. After completing the measurements, the means, SDs, and minimum distance between the GPA and the CEJ of the maxillary
teeth were calculated for all three PVH categories.

Statistical Analyses

All statistical analyses were performed using R statistical software.20 A generalized linear model (GLM) formula analysis was performed. The variables GPA, PVH, gender, and age were tested individually along with their two-way and three-way interactions.

Results

A total of 66 half palates were included in the study. Out of the 66 sections, 12 sections had shallow (S) PVH, 20 sections had average (A) PVH, and 34 sections had a high (H) PVH. The PVH distribution based on gender was as follows:

- S: M = 2, F = 10
- A: M = 6, F = 14
- H: M = 22, F = 12

There was no variation and no effect between the location of the GPA and the age of the cadavers.

The GPA location based upon the measured PVH is demonstrated in Table 1. Regarding the first and second premolar and first and second molar, the distance from the CEJ to the GPA was $10 \pm 1.2$ mm, $10.8 \pm 1.7$ mm, $12.2 \pm 1.8$ mm, and $12.0 \pm 1.9$ mm for the average PVH, respectively, and $10.9 \pm 1.2$ mm, $13.0 \pm 1.3$ mm, $14.0 \pm 1.1$ mm, and $14.5 \pm 1.3$ mm for the high PVH, respectively. The minimum distance from the CEJ to the GPA location ranged from 6 to 12 mm, depending on the PVH. Table 2 shows the measurements from the GPA to the CEJ, measured from the maxillary canine to the second molar, showing means and SDs separately for male and female cadavers. Table 3 shows the variables PVH, gender, and age and their two-way and three-way interactions with the GPA. There was no three-way interaction between PVH, gender, and age with the GPA location. On the contrary, there was a two-way interaction between the PVH and the gender of the cadavers with the GPA location. Specifically, for the shallow PVH, there was a statistically significant difference between male and female cadavers. Only the PVH as an independent variable had a statistically significant correlation with the GPA location.

Figure 7 depicts the triple interaction between PVH, age, and gender with the GPA location. The y-axis shows the GPA location (in millimeters), and the x-axis shows the age of the cadavers (in years). The graph shows the statistically

<table>
<thead>
<tr>
<th>Table 1 Cadaver Measurements (from the GPA to the CEJ) from the Maxillary Canine to the Second Molar by PVH Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PVH type</strong></td>
</tr>
<tr>
<td>Shallow (S)</td>
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<tr>
<td>First premolar</td>
</tr>
<tr>
<td>Second premolar</td>
</tr>
<tr>
<td>First molar</td>
</tr>
<tr>
<td>Second molar</td>
</tr>
<tr>
<td>Average (A)</td>
</tr>
<tr>
<td>First premolar</td>
</tr>
<tr>
<td>Second premolar</td>
</tr>
<tr>
<td>First molar</td>
</tr>
<tr>
<td>Second molar</td>
</tr>
<tr>
<td>High (H)</td>
</tr>
<tr>
<td>First premolar</td>
</tr>
<tr>
<td>Second premolar</td>
</tr>
<tr>
<td>First molar</td>
</tr>
<tr>
<td>Second molar</td>
</tr>
</tbody>
</table>

PVH = palatal vault height; GPA = greater palatine artery; CEJ = cementoenamel junction.
There is no effect of age at the GPA location. Figure 8 excludes the age and shows the two-way interaction between the gender of the cadavers and the GPA location at the shallow PVH only. The graph shows a statistically significant difference for the shallow PVH between male and female cadavers.

### Discussion

The location of the GPA from the CEJ of maxillary posterior teeth varies in distance depending on the underlying bony anatomy of the palatal vault.

In the present study, 35 Caucasian cadavers were sectioned in the palate to visualize the course of the GPA and to measure the distance from the CEJ of the corresponding teeth (canine to second molar). PVH was measured vertically from the midpalatal suture to the level of the CEJ of the maxillary first molars using a custom stent fabricated for each cadaver specimen. Categorization of the PVH was done according to height: shallow (9 to 11 mm), average (12 to 14 mm), and high (≥15 mm). For the average PVH, the mean distance from the CEJ to the GPA was 8.6 ± 1.3 mm for the canine, 10.0 ± 1.2 mm for the first premolar, 10.8 ± 1.7 mm for the second premolar, 12.2 ± 1.8 mm for the first molar, and 12.0 ± 1.9 mm for the second molar. For the high PVH, the mean distance from the CEJ to the GPA was 10.0 ± 1.3 mm for the canine, 10.9 ± 1.2 mm for the first premolar, 13.0 ± 1.7 mm for the second premolar, 12.2 ± 1.8 mm for the first molar, and 14.0 ± 1.1 mm for the second molar. For the high PVH, the mean distance from the CEJ to the GPA was 10.0 ± 1.3 mm for the canine, 10.9 ± 1.2 mm for the first premolar, 13.0 ± 1.7 mm for the second premolar, 12.2 ± 1.8 mm for the first molar, and 14.0 ± 1.1 mm for the second molar. For the high PVH, the mean distance from the CEJ to the GPA was 10.0 ± 1.3 mm for the canine, 10.9 ± 1.2 mm for the first premolar, 13.0 ± 1.7 mm for the second premolar, 12.2 ± 1.8 mm for the first molar, and 14.0 ± 1.1 mm for the second molar. For the high PVH, the mean distance from the CEJ to the GPA was 10.0 ± 1.3 mm for the canine, 10.9 ± 1.2 mm for the first premolar, 13.0 ± 1.7 mm for the second premolar, 12.2 ± 1.8 mm for the first molar, and 14.0 ± 1.1 mm for the second molar. For the high PVH, the mean distance from the CEJ to the GPA was 10.0 ± 1.3 mm for the canine, 10.9 ± 1.2 mm for the first premolar, 13.0 ± 1.7 mm for the second premolar, 12.2 ± 1.8 mm for the first molar, and 14.0 ± 1.1 mm for the second molar. For the high PVH, the mean distance from the CEJ to the GPA was 10.0 ± 1.3 mm for the canine, 10.9 ± 1.2 mm for the first premolar, 13.0 ± 1.7 mm for the second premolar, 12.2 ± 1.8 mm for the first molar, and 14.0 ± 1.1 mm for the second molar.
Table 3  Analysis of Deviance (Type II Tests) for PVH, Gender, and Age Individually and as Two-Way and Three-Way Interactions with GPA Location

<table>
<thead>
<tr>
<th>Variables</th>
<th>Chi square</th>
<th>df</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td>PVH</td>
<td>49.6</td>
<td>2</td>
<td>&lt; .001*</td>
</tr>
<tr>
<td>Gender</td>
<td>1.0</td>
<td>1</td>
<td>&lt; .3163</td>
</tr>
<tr>
<td>Age</td>
<td>0.4</td>
<td>1</td>
<td>&lt; .5475</td>
</tr>
<tr>
<td>PVH:Gender</td>
<td>32.4</td>
<td>2</td>
<td>&lt; .001*</td>
</tr>
<tr>
<td>PVH:Age</td>
<td>1.4</td>
<td>2</td>
<td>&lt; .4935</td>
</tr>
<tr>
<td>Gender:Age</td>
<td>1.3</td>
<td>1</td>
<td>&lt; .2621</td>
</tr>
<tr>
<td>PVH:Gender:Age</td>
<td>0.9</td>
<td>2</td>
<td>&lt; .6520</td>
</tr>
</tbody>
</table>

PVH = palatal vault height; GPA = greater palatine artery.
*Statistically significant.

Fig 7  This graph depicts the three-way interaction between PVH, age, and gender with the GPA location. The x-axis (top and bottom) shows the age of the cadavers in years, and the y-axis shows the location of GPA (in millimeters). The graph shows a statistically significant difference between male and female cadavers regarding the location of the GPA and the CEJ at the shallow PVH (boxes 3 and 6). There is no effect between age and the GPA location.

Fig 8  This graph excludes the age from Fig 7 and shows the two-way interaction between gender and PVH. The x-axis shows the PVH type, and the y-axis shows the GPA location (in millimeters). The graph shows a statistically significant difference between male and female cadavers for the shallow PVH.
customized stents, to correlate PVH with the distance of GPA to the CEJ of maxillary teeth, and to identify that the gender is a significant factor for the GPA location, especially for shallow PVH.

In 2011, Fu et al assessed the location of the greater neurovascular bundle in 11 fresh male cadaver heads. The mean distance from the CEJ to the neurovascular bundle at the area of first premolar was 12.2 ± 2 mm, and in the area of the first molar, the mean distance was 13.1 ± 2 mm. The average PVH was 14.1 ± 2.5 mm, but the authors did not show any correlation between the different categories of PVH and the neurovascular bundle. 21

In 2014, Yu et al evaluated the location of the GPA in 24 embalmed Korean adult cadavers and 25 dry skulls. 18 They reported the distances from the CEJ to the lateral branch of the GPA as 9.04 ± 2.93 mm for the canine, 11.12 ± 1.89 mm for the first premolar, 13.51 ± 2.08 mm for the second premolar, 13.76 ± 2.86 mm for the first molar, and 13.91 ± 2.20 mm for the second molar. However, the PVH was not taken into consideration, and no correlations have been made regarding the GPA position and the PVH. The results are in accordance with the high PVH category of the present study.

In 2014, Kim et al examined 22 embalmed Korean adult cadavers. 22 The palatal vaults were divided into only two categories: high and low, relative to the palatal width and depth. In cadavers with a high PVH, the authors identified the distance between the CEJ and the maxillary teeth as 11 ± 3.2 mm for the canine, 12.1 ± 2.7 mm for the first premolar, 13.9 ± 1.6 mm for the second premolar, 13.3 ± 2.5 mm for the first molar, and 14.2 ± 3.1 mm for the second molar. High PVH was associated with a greater distance between the CEJ and the gingival margins of the adjacent teeth. Finally, the authors suggest the area of the second premolar as the ideal donor tissue area, as the height and width allow the harvesting of a larger connective tissue graft. 22

All of the aforementioned studies, including the present study, agree that there is greater distance from the CEJ of the maxillary teeth to the GPA in cases with high PVH. The GPA is located more deeply, allowing for more connective tissue to be harvested. In addition, there was no difference between the ethnicity groups of the cadavers; all had similar distances from the CEJ to the maxillary teeth, and male cadavers were found to have a higher PVH. These numbers should alert clinicians that there is less vertical height available for connective tissue harvesting than has been previously reported in the literature.

Conclusions

In the present cadaver study, most PVHs were high (≥ 15 mm), with the maximum mean distance from the GPA to the CEJ for the vault type ranging between 10.0 mm at the canine and 14.5 mm at the second molar. The gender was identified as a significant factor regarding GPA location, especially for shallow PVH.

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References


