Original Article

Detection of the gubernacular canal and its attachment to the dental follicle may indicate an abnormal eruption status

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ABSTRACT

Objectives: To evaluate and compare the detection of gubernacular canals (GC) and their characteristics in normal and abnormal tooth eruption.

Materials and Methods: Patients with unerupted teeth were classified according to sex and age. Each tooth was classified according to dental group, eruption status, formation status, angulation, and GC detection. The opening of the GC in the alveolar crest and the attachment sites in relation to the dental follicle were assessed. Data were analyzed by the chi-square and Kruskal-Wallis tests, with a significance level of 5%.

Results: Cone-beam computed tomography scans of 159 patients were evaluated. The final sample ($N = 598$) consisted of 423 teeth with normal eruption, 140 impacted teeth, and 35 teeth with delayed eruption. The overall detection rate of GC was 90.6%. These rates were 94.1%, 87.1%, and 62.9% for normal eruption, impacted teeth, and delayed eruption, respectively. GC detection rates were higher in the early stages of tooth formation in normal tooth eruption and in impacted teeth. The rate of GC detection was even lower in delayed teeth when they were angulated. Unusual attachment sites of the GC to the dental follicle were associated with abnormal eruption status.

Conclusions: The results of the present study suggest that GC characteristics may indicate an abnormal eruption status. (*Angle Orthod.* 2019;89:781–787.)

KEY WORDS: Cone-beam computed tomography; Tooth germ; Tooth, unerupted; Tooth eruption

INTRODUCTION

The dental follicle of a permanent tooth is connected to the lamina propria of the overlying gum by a structure composed of connective tissue,[1,2] named the gubernacular cord, which originates in the dental lamina. Osteoblastic activity is regulated by the presence of epithelial tissue, which respects the boundaries of the gubernacular cord and forms a canal around it, the gubernacular canal (GC).[1,3–5] The gubernaculum dentis (gubernacular cord and GC) is considered important in the eruption process[6] since it represents the eruption path of the tooth through the bone.[7,8]

Recently, the GC has been revisited by means of panoramic radiography, multidetector computed tomography, and cone-beam computed tomography (CBCT).[6,9] This structure is described as a radiolucent/hypodense corticated canal connected to the dental follicle space.[9] It has been suggested that the GC forms an eruption pathway, and therefore, its absence may indicate failure in tooth eruption.[9] However, this structure is also observed in teeth with eruption failure.[6] The relationship between failure of tooth eruption and GC characteristics remains unclear.

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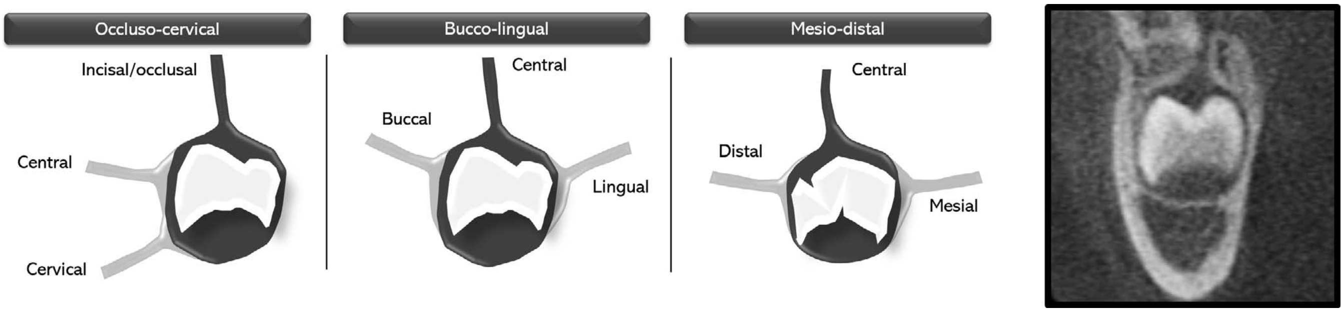

Figure 1. Classification of the attachment sites of the gubernacular canal (GC) to the dental follicle in three aspects: occluso-cervical, bucco-lingual, and mesio-distal. The bright-gray GC represents an unusual location of attachment to the dental follicle. On the right, a cropped CBCT coronal image of a lower premolar exhibiting a usual location of CG attachment.

CBCT is not indicated on a routine basis because of the risks of ionizing radiation, especially for children. However, this method is a valuable tool for diagnosis and treatment planning of selected cases in orthodontics, including those in which interceptive orthodontic and/or surgical treatments are considered for teeth with positional or eruption anomalies.[10,11] Volumetric data allow correct identification of tooth morphology and the relationship with adjacent structures, thus contributing to clinical decision making (eg, whether to extract or to consider extrusion of a tooth).[12] Higher radiation doses are applied in CBCT imaging compared with conventional radiographic examination. Thus, when CBCT is indicated, all efforts must be made to obtain the greatest amount of clinically relevant information that potentially contributes to patient outcome. Routine use of CBCT to evaluate the presence of GC is not justified. However, if a CBCT scan has been taken because of clinically justified reasons, assessment of the presence of GC and its characteristics can contribute to treatment planning in orthodontics.

The aim of the present study was to compare detection rates of GC, its imaging characteristics, and features of its corresponding tooth between teeth with normal and abnormal eruption status (ie, delayed and impacted).

MATERIALS AND METHODS

Sample Selection

This study was approved by the institutional review board of the School of Dentistry of Piracicaba, State University of Campinas, Piracicaba, São Paulo, Brazil. The sample was composed of unerupted teeth observed on CBCT scans from the institutional image database, which were acquired for different clinical reasons. Exclusion criteria were scans showing movement artifacts, supernumerary teeth (since these teeth do not have a defined eruption pattern), and teeth in an advanced eruption stage (ie, cusps beyond the level of the alveolar crest). The CBCT scans were acquired with two different devices: OP300 (Instrumentarium, Tuusula, Finland) and Picasso-Trio (E-WOO Technology Giheung-gu, Republic of Korea). The exposure parameters were selected according to the clinical indication for each patient. The scans were analyzed using the software provided by each CBCT manufacturer, OnDemand3D (Cybermed, Inc, Seoul, Republic of Korea) and Ez3D (E-WOO Technology, Giheung-gu, Republic of Korea), respectively.

Sample Evaluation

All scans were independently evaluated by two oral and maxillofacial radiologists in a dimly lit and quiet environment. For calibration purposes, 50 cases were evaluated by both radiologists together. After complete evaluation of the sample, the data obtained by the two observers were compared, and in cases of disagreement, a consensus was reached by simultaneous reevaluation with a third oral and maxillofacial radiologist. Patient sex and age were recorded, and each tooth was classified according to dental group (upper incisors, upper canines, upper premolars, upper molars, lower incisors, lower canines, lower premolars, and lower molars). The following parameters were assessed: eruption status (normal, delayed, or impacted), formation status (crown formation, root formation, open apex, or closed apex), angulation (normal, inclined, horizontal, or inverted), and GC detection (detected, not detected, indistinguishable from the periodontal ligament space [PLS] of the predecessor tooth or indistinguishable from an alveolar bone resorption process). If GC was detected, the site of its opening in the alveolar crest (buccal, lingual, or central, or in the PLS of the predecessor tooth) and the site of its attachment to the dental follicle (Figure 1) were further assessed.

Regarding eruption status, the teeth were classified as impacted when a physical barrier was detected (eg, supernumerary teeth, lack of space in the dental arch, and deviated tooth germ).[13] Delayed eruption was defined when the unerupted tooth was intraosseous, without any visible mechanical barriers, and the difference between patient age and the mean eruption age of the dental group was greater than twice the standard deviation established for that dental group.[13–15] The mean eruption ages that served as references in our study were obtained from a previous study[14] involving individuals from the same geographical region as those of the current sample because of possible variability among population groups. The mean eruption age of third molars from this geographical region was not available and was therefore adapted from a previous study[15] by calculating the mean age from the 50% probability of complete eruption status for third molars according to sex. Cases that had no visible mechanical barriers and whose patient age was within the mean eruption age were classified as normal eruption.

Statistical Analysis

Statistical analyses were performed using SPSS v.22.0 software (SPSS, Inc, Chicago, Ill). GC detection, eruption status, tooth formation, and angulation were compared by the chi-square test. GC characteristics were compared by the Kruskal-Wallis and Dunn tests. The level of significance was set at $P < .05$.

RESULTS

Scans from 159 patients were selected (88 males and 71 females), ranging in age from 5 to 36 years (mean age 17.20 $\pm$ 8.65 years), and 762 teeth were evaluated. In 164 teeth, the presence of GC was uncertain because the hypodense area was indistinguishable from the PLS of the deciduous tooth (48 cases, mostly premolars) or from resorption of the alveolar bone ridge (116 cases, mostly molars). These teeth were excluded from the final sample for comparative purposes. To differentiate GC from alveolar bone resorption, the teeth were carefully evaluated on the three reconstruction planes, and GC had to be identified in at least two planes. The final sample for comparative statistical analysis included 598 teeth, divided into eight dental groups: upper incisors (n = 20; 15 central incisors and 5 lateral incisors), upper canines (n = 99), upper premolars (n = 91; 48 first premolars and 43 second premolars), upper molars (n = 145; 26 second molars and 119 third molars), lower incisors (n = 2; two lateral incisors), lower canines (n = 25), lower premolars (n = 62; 30 first premolars and 32 second premolars), and lower molars (n = 154; 36 second molars and 118 third molars). Considering eruption status, there were 423 teeth (70.7%) with normal eruption, 140 impacted teeth (23.4%), and 35 delayed teeth (5.9%).

Table 1. Absolute Frequency and Detection Rate of GC by Dental Group, According to Eruption Status[a]

Dental Group	Eruption Status	GC, n: Not Detected	GC, n: Detected	Detection Rate, %	*P**
Upper incisors	Normal	1	6	85.7[A]	
	Impacted	0	11	100[A]	.376
	Delayed	0	2	100[A]	
	Total	**1**	**19**	**95**	
Upper canines	Normal	7	66	90.4[A]	
	Impacted	5	10	63.6[B]	**.012**
	Delayed	4	7	66.7[B]	
	Total	**16**	**83**	**83.8**	
Upper premolars	Normal	7	75	91.5[A]	
	Impacted	0	2	100[AB]	**.001**
	Delayed	4	3	42.9[B]	
	Total	**11**	**80**	**87.9**	
Upper molars	Normal	2	107	98.2[A]	
	Impacted	2	31	93.9[A]	**.009**
	Delayed	1	2	66.7[B]	
	Total	**5**	**140**	**96.6**	
Lower incisors	Normal	0	1	100	
	Impacted	—	—	—	—
	Delayed	0	1	100	
	Total	**0**	**2**	**100**	
Lower canines	Normal	2	7	77.8[A]	
	Impacted	4	7	63.6[A]	.708
	Delayed	1	4	80[A]	
	Total	**7**	**18**	**72**	
Lower premolars	Normal	6	41	87.2[A]	
	Impacted	6	4	40[B]	**.001**
	Delayed	3	2	40[AB]	
	Total	**15**	**47**	**75.8**	
Lower molars	Normal	0	95	100[A]	
	Impacted	1	58	98.3[A]	.204
	Delayed	0	0	0	
	Total	**1**	**153**	**99.4**	
All groups	Normal	25	398	94.1[A]	
	Impacted	18	123	87.1[B]	**<.001**
	Delayed	13	21	62.9[C]	
	Total	**56**	**542**	**90.6**	

[a] Different superscript letters indicate a statistically significant difference between the detection rate of the GC in the eruption statuses.

* Chi-square test comparing the detection of GC between dental statuses for each dental group. Statistically significant differences ($P<.05$) are in bold font.

Table 1 summarizes the sample distribution according to dental group, eruption status, and GC detection. In general, GC was detected in 90.6% of the cases (Figure 2). This rate was significantly lower among teeth with delayed eruption and impacted teeth (62.9% and 87.1%, respectively) compared with those with normal eruption (94.1%). These differences in detection according to eruption status were uneven among dental groups (Table 1). Considering only normal and delayed teeth, delayed eruption was found in 34.2% of teeth in which GC was not detected. In contrast, when GC was detected, delayed eruption was observed in only 5.2% of the teeth.

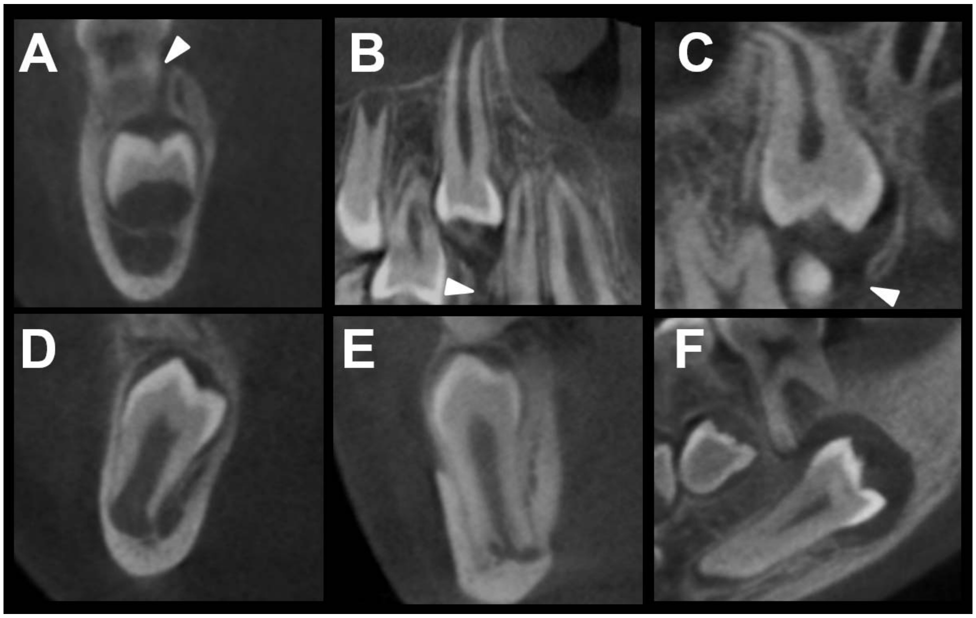

Figure 2. CBCT images of the gubernacular canal (GC) detected in (A) teeth with normal eruption, (B) teeth with delayed eruption, and (C) impacted teeth (arrows indicate GC opening in the alveolar crest). GC not detected in (D) normal eruption, (E) delayed eruption, and (F) impacted teeth.

Table 2 shows the detection of GC among the different eruption statuses according to characteristics of the teeth (formation and angulation). Significant differences in GC detection were found for the formation status of teeth in normal eruption ($P = .0001$) and in impacted teeth ($P = .003$), with higher detection rates in the earliest stages of tooth formation. Most teeth with a closed apex had an abnormal eruption status, and GC detection was lower (62.5% for delayed teeth and 75% for impacted teeth).

The characteristics of GC are shown in Table 3. The anterior and premolar groups were pooled since they represented teeth with primary predecessors. The most common attachment sites of GC to the dental follicle were on the occlusal aspect of the follicle (93.2%) and centrally in the buccal-lingual and mesio-distal directions (96.3% and 90%, respectively). Other locations ranged from 1.1% to 7%. Therefore, the cases in which the attachment was located on the incisal/occlusal aspect of the follicle and centrally in the buccal-lingual and mesio-distal directions were classified as usual location (87.1%), while those at different sites were classified as unusual location (Figure 3).

Table 2. Absolute Frequency and Detection Rate of GC According to Tooth Formation and Angulation Among the Different Eruption Statuses

	Eruption Status											
	Normal				Delayed				Impacted			
Teeth Characteristics	GC Not Detected	GC Detected	Detection Rate, %	*P**	GC Not Detected	GC Detected	Detection Rate, %	*P**	GC Not Detected	GC Detected	Detection Rate, %	*P**
Formation												
Crown formation	2	139	98.6	**.0001**	—	—	—	.693	0	21	100.0	**.003**
Root formation	18	238	93.0		1	1	50.0		1	38	97.4	
Open apex	2	18	90.0		0	1	100.0		3	21	87.5	
Closed apex	3	3	50.0		12	20	62.5		14	42	75.0	
Total	25	398			13	22			18	122		
Angulation												
Normal	18	321	94.7	.559	4	9	69.2	**.043**	10	49	83.1	.229
Angulated	6	68	91.9		9	7	43.8		8	50	86.2	
Horizontal	1	9	90.0		0	6	100.0		0	21	100.0	
Inverted	—	—	—		—	—	—		0	2	100.0	
Total	25	398			13	22			18	122		

* Chi-square test comparing the detection of GC according to the characteristics of the tooth. Statistically significant differences ($P<.05$) are in bold font.

Table 3. Absolute Frequency and Statistical Significance of CG Characteristics Observed in Teeth With (Anterior/Premolars) and Without (Molars) Predecessor Primary Tooth for Normal, Delayed, and Impacted Teeth[a]

Teeth	Eruption Status	GC Characteristics			
		Opening			
		Lingual	Central	Buccal	PLS
Anterior/premolars	Normal[A]	180	7	2	7
	Delayed[AB]	14	2	3	0
	Impacted[B]	26	4	4	0
	Total	220	13	9	7
Molars	Normal[A]	13	189	0	0
	Delayed[A]	0	2	0	0
	Impacted[A]	3	84	2	0
	Total	16	275	2	0
		Attachment Site			
		Usual		Unusual	
Anterior/premolars	Normal[A]	180		16	
	Delayed[B]	7		12	
	Impacted[B]	19		15	
	Total	206		43	
Molars	Normal[A]	190		12	
	Delayed[AB]	2		0	
	Impacted[B]	74		15	
	Total	266		27	

[a] PLS indicates periodontal ligament space. Different superscript letters indicate statistically significant differences between eruption statuses (Kruskal-Wallis and Dunn's tests).

The sites of GC opening in the alveolar crest differed significantly between normally erupting and impacted teeth in the anterior/premolar group ($P < .05$). Teeth with normal eruption exhibited unusual locations of GC attachment to the dental follicle in 7% of the cases, while the prevalence of unusual locations was significantly higher (29.2%) in teeth with abnormal eruption ($P < .05$).

DISCUSSION

The detection of GC among the dental groups ranged from 72% for lower canines to 96.6% for upper molars, regardless of eruption status. Detection rates of the GC ranging from 43.7% to 100% have been reported,[9] and teeth with delayed eruption exhibited the lowest detection rates.[6] In the present study, the highest detection rates were observed for normally erupting teeth among all dental groups (94.1%), followed by impacted teeth (87.1%) and teeth with delayed eruption (62.9%).

When the GC was detected, only 5.2% of the teeth had delayed eruption. However, when the GC was not detected, delayed eruption of the teeth occurred in 34.2% of the cases. This corresponded to a six-fold higher chance of teeth having delayed eruption when the GC was not detected.

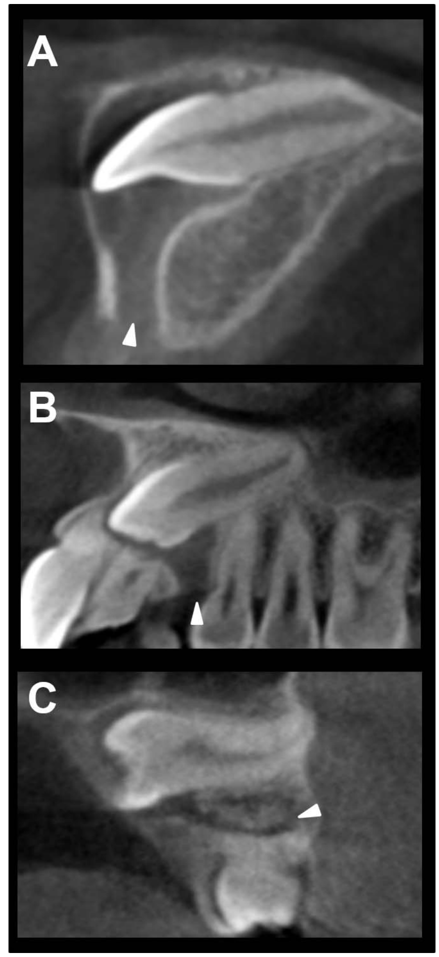

Figure 3. CBCT images of examples of unusual attachment sites of the gubernacular canal (GC) to the dental follicle. (A) Upper anterior tooth with delayed eruption exhibiting CG attachment in the lingual (bucco-lingual aspect) and central (occlusal-cervical aspect) regions of the dental follicle. (B) Impacted upper anterior tooth showing attachment of the GC to the dental follicle in the cervical portion of the crown. (C) Impacted upper premolar exhibiting unusual GC attachment in the cervical region of the crown. Arrows indicate the GC.

There is no consensus in the literature about the existence of GC in permanent teeth without primary predecessors (ie, permanent molars). It is believed that their dental germs originate directly from a posterior extension of the dental lamina.[16] Some early reports suggested the presence of GC in permanent molars and named them *molar gubernacular cord*, while others[1] stated that this structure was exclusively found in permanent teeth with primary predecessors. The current results confirmed the presence of GC in molars. In fact, the highest rates of GC detection were observed among molars. However, the presence of this anatomical structure in primary teeth is still unclear, and further studies are required.

Among teeth with abnormal eruption, those with a horizontal position exhibited slightly higher GC detection rates than those with more favorable positions (normal and angulated). It may be speculated that angular deviation in a tooth germ with abnormal eruption impairs or delays resorption of the gubernacular cord. Thus, this structure remains detectable even though the tooth is unlikely to erupt. Further studies of delayed eruption are necessary to clarify this finding.

In teeth with predecessors, the GC opening was found mainly on the lingual aspect of the alveolar crest. In molars, the GC opening was usually located in the center of the alveolar crest. These findings were consistent with previous knowledge about the origin of the GC in anterior and premolar teeth, where it arises from the predecessor tooth germ, and in molar teeth, where its origin is a posterior extension of the dental lamina.[16] Unusual attachment sites of the GC to the dental follicle were significantly more common among teeth with abnormal eruption status. These results suggest that, if the GC is seen connected to the follicular space in less typical locations on CBCT, the teeth are more likely to have abnormal eruption.

The process of tooth eruption is not fully understood. Studies have demonstrated the involvement of alveolar bone, dental follicle, osteoclasts, osteoblasts, and cytokines.[17] The dental follicle seems to play an essential role in triggering bone remodeling of the alveolar process, which is required for tooth eruption.[17] The gubernacular cord, as an extension of the dental follicle, may also have some influence on this complex process. The results suggested that observing the presentation of the GC on CBCT may help anticipate tooth eruption problems. However, numerous other factors also affect the eruption process, such as hormonal, systemic, and morphological factors related to jaw growth and development.[18,19]

Detection of the GC might not be straightforward in some cases because of variations in trabecular bone microarchitecture or proximity to primary teeth. Particularly in premolar regions, the hypodense band corresponding to the periodontal ligament of primary teeth may be indistinguishable from a GC of the permanent successor germ. Also, in the molar region, a large hypodense area is commonly seen above the tooth germ. In this case, distinction between the GC and the resorption process requires careful evaluation.

Limitations of this study were inherent to the limitations of cross-sectional studies. The data collected in this study corresponded to the imaging features at a specific time point and did not show the sequences of events during tooth eruption and variations in the GC that may have occurred over time. Longitudinal studies should be conducted to further understand the changes that the GC undergoes during tooth development and eruption, as well as the possible effects of GC features on the eruption process. However, the use of ionizing radiation for this purpose would not be justified.

The present study adds information about the presentation of the GC, which may contribute to clinical decision making in cases in which CBCT is available. Requesting a CBCT to assess the presence and imaging characteristics of the GC remains unjustified. Principles of radiation protection such "as low as reasonably achievable" (ALARA) and "as low as diagnostically acceptable" (ALADA)[20,21] must be followed, especially because patients with unerupted teeth are usually children or young adults who are more vulnerable to the potential biological effects of ionizing radiation.

CONCLUSIONS

- GC detection rates are lower among teeth with abnormal eruption status, and careful evaluation is therefore recommended when this structure is not detected.
- When the GC is attached to the dental follicle at an unusual site, the corresponding tooth is more likely to have an abnormal eruption process.
- Further investigation of these parameters can contribute to treatment planning involving unerupted teeth, whether to consider tooth extraction, extrusion, or monitoring.

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DISCLOSURE

The authors deny any conflict of interest.

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