MMDJ MEANDROS MEDICAL AND DENTAL JOURNAL

September 2025 26(3):295-302

Meandros Medical and Dental Journal
doi: 10.69601/meandrosmdj.1664841

Research Article

EVALUATION OF GUBERNACULUM DENTIS CHARACTERISTICS IN IMPACTED AND UNERUPTED PERMANENT TEETH: A CBCT-BASED STUDY

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Received: *27 March 2025*
Revised: *02 June 2025*
Accepted: *11 June 2025*
Published: *22 September 2025*

ABSTRACT

Objective: This study aims to characterize the imaging features of the gubernaculum dentis in impacted or unerupted permanent teeth. It also investigates whether these features differ between individuals with eruption-related pathologies and those without associated pathological conditions.

Materials and Methods: A case-control design was employed, comprising 110 individuals in the study group (pathology-associated impacted/unerupted teeth) and 112 individuals in the control group (impacted/unerupted teeth without pathology). Categorical variables were analyzed using Pearson's Chi-Square test, which is appropriate for evaluating associations between categorical variables. In instances where multiple group comparisons were necessary, the Bonferroni-corrected Z-test was applied to adjust for the increased risk of Type I error due to multiple testing, thereby maintaining the overall statistical validity.

Results: A statistically significant association was observed between GD status (absent, present, or enlarged) and group classification (pathology vs. control; $p < 0.001$). Specifically, GD absence was more prevalent in the pathology group (53.6%) compared to controls (26.1%). No significant age-related differences were detected between genders ($p = 0.307$).

Conclusion: The findings demonstrate an inverse relationship between GD presence and pathological conditions associated with impacted or unerupted teeth. This suggests that GD absence or enlargement may serve as a radiographic marker for underlying odontogenic pathologies. Further studies are warranted to elucidate the mechanistic role of GD in eruption disturbances.

Keywords: Pathology; Gubernaculum tract; Impacted tooth; Gubernaculum canal; Ubernaculum tract

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INTRODUCTION

Anatomically, the gubernaculum dentis (GD) is defined as an eruption channel for permanent teeth, establishing a connection between the dental follicle and the gingiva. This structure has been extensively documented in the literatüre (1). Histologically, the gubernaculum dentis (GD) consists of two main components: a bony canal that surrounds the gubernacular cord (GCo) and a fibrous band known as the GCo. The bony canal extends from the pericoronal follicular tissue of the developing successional or accessional tooth to the alveolar bone crest, where it opens into the overlying gingiva. The GCo itself is composed primarily of epithelial remnants originating from the dental lamina (2).

The gubernacular tract (GT) is composed of fibrous connective tissue that supports the eruptive movement of the permanent tooth. It contains blood vessels, lymphatics, nerves, and epithelial cell remnants from the dental lamina. Furthermore, the GT plays a crucial role in tooth eruption by producing various chemical mediators that stimulate osteoclastic bone resorption. This mechanism ensures that each erupting permanent tooth follows a designated eruption pathway until it reaches its final position guided by the oral mucosa.

Although the GCo is not anatomically associated with deciduous teeth, it has been hypothesized to guide the eruption trajectory of permanent teeth. In molars lacking deciduous predecessors, the dental follicle maintains a connection to the oral mucosa via the GCo (3). Despite its potential role in facilitating eruption, clinical research on the GCo remains limited (4). Interestingly, surgical removal of the GCo does not completely inhibit tooth eruption, implying compensatory mechanisms (5).The GCo undergoes dynamic remodeling—widening and contracting via resorption—during the eruption process. It is postulated that tooth movement aligns with the resorptive pathway of the GCo (6).

Due to their thin structure and anatomical location within spongy bone, these components are challenging to distinguish from bone marrow voids in conventional two-dimensional imaging (2). Radiographic imaging typically visualizes the GC as a bony structure, whereas the GCo remains undetectable. However, subsequent studies utilizing multidetector computed tomography (MDCT) and cone beam computed tomography (CBCT) have provided further insights into their presence and imaging characteristics (7)(8).

Many clinicians have limited awareness of the gubernacular canal (GC), and it is frequently overlooked in radiographic assessments. Due to its small diameter of approximately 1 to 3 mm, the GC can resemble alveolar bone resorption surrounding erupting teeth as they approach the alveolar crest, making it difficult to detect on CBCT images. Additionally, in the maxillary premolar region, the visualization of the GC in sagittal and coronal CBCT planes is often hindered by overlapping radiographic projections of deciduous and permanent teeth (7).

Obstructed eruption, including tooth impaction, has been linked to morphological anomalies of the gubernacular cord (GCo), such as its absence or structural distortion. Emerging evidence posits that the GC, a conduit connecting the dental follicle to the oral mucosa, may play a critical role in guiding tooth eruption. Dysregulation of this pathway is hypothesized to contribute to ectopic eruption patterns.

Furthermore, adenomatoid odontogenic tumors (AOTs) are theorized to originate from epithelial remnants of the dental lamina within the GC microenvironment. This hypothesis is supported by the frequent localization of AOTs near unerupted teeth, where GC activity is prominent. Recent studies have also identified a potential pathogenic association between odontomas—benign odontogenic tumors—and GC aberrations. Specifically, persistent GC remnants or abnormal signaling within the gubernacular tract may drive dysplastic mineralization processes characteristic of odontomas (6)(7,9). These findings underscore the GC's dual role in both physiologic eruption and the pathogenesis of odontogenic lesions.

Despite its potential clinical significance, the GC has been the subject of only limited radiological investigation, and its exact role in the process of tooth eruption remains inadequately defined. Existing studies offer insufficient data regarding the imaging characteristics of the GC, particularly in cases involving eruption disturbances or related pathological conditions. Addressing this gap, the present study aims to provide a thorough radiological analysis of the GC in impacted or unerupted permanent teeth, with an emphasis on identifying whether its imaging features are affected by the presence of eruption-related anomalies or associated pathological findings. Through this focused approach, the study seeks to contribute meaningful insights into the diagnostic relevance of GC evaluation in clinical radiology.

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MATERIALS AND METHODS

This retrospective study was conducted using data from Hacettepe University, with written permission obtained from the institution. Ethical approval was granted by the Ethics Committee of Çankırı Karatekin University following the submission of the institutional permission document. The study utilized CBCT images of 2,500 patients of all ages and genders, originally acquired for routine treatments and clinical evaluations, and archived in the Oral and Maxillofacial Radiology Department of Hacdettepe University Faculty of Dentistry.

A total of 110 patients (53 females [48.2%] and 57 males [51.8%]) with pathology associated with impacted or unerupted teeth were included in the study group, while 112 individuals (57 females [50.9%] and 55 males [49.1%]) with impacted or unerupted teeth but without associated pathology formed the control group. Follicle sizes larger than 5 mm were accepted indicators of related pathologies, including odontogenic keratocyst, dentigerous cyst, adenomatoid odontogenic tumor, and odontomas, in the scope of radiological preliminary diagnosis. However, due to the unavailability of biopsy reports, definitive histopathological diagnoses could not be established, and the specific nature of these lesions remains undetermined.

Inclusion criteria

• One or more teeth fully embedded in the bone met the inclusion criteria.
• The study and control groups were matched for age and gender distribution.
• There was no effort to determine if the tooth was impacted or unerupted.
• Exclusion criteria encompassed low-quality CBCT images, including those affected by motion artifacts or the presence of metal objects that obscured visualization of the developing tooth and gubernacular canal (GC).

The CBCT images were acquired using an i-CAT Next Generation CBCT scanner (Imaging Sciences International, Hatfield, PA, USA) with the following parameters: 5 mA (tube current), 120 kVp, exposure time of 14.7–17.8 seconds, 16 × (8–13) cm and 23 × 17 cm (fields of view), and voxel sizes between 0.20 and 0.30 mm. CBCT images were evaluated by two oral and maxillofacial radiologists: Z.O., with five years of experience, and O.B.D., with four years of experience. To ensure consistency and reliability in image interpretation, a calibration phase was conducted wherein both observers jointly assessed an initial subset of 50 images and reached a consensus on the evaluation criteria. Following this standardization process, the remaining images were randomly distributed between the two observers, who independently performed their evaluations. For each image, a single consensus-based evaluation was recorded to ensure uniformity in data collection. All image evaluations were conducted on the same computer in a dimmed room, where the brightness and contrast could be adjusted as needed for evaluation.

GD presence, absence, or enlarged

The evaluation focused on pathological conditions such as resorption in impacted or unerupted teeth, root resorption in adjacent teeth, and follicular space widening. External root resorption was identified by a clear loss of continuity in the root surface at the contact site. Follicular size was measured at its maximum width from the crown to the follicular periphery, with a dimension greater than 3 mm classified as follicular enlargement.

In sagittal and coronal CBCT images, the gubernaculum dentis (GD) typically appears as a low-density tract with well-defined corticated margins, measuring approximately 1 to 3 mm in diameter. On axial CBCT images, it is observed as a low-density, rounded area within the alveolar bone crest. Morphological alterations were identified in cases where the GD was enlarged (>5 mm in diameter), deformed, or obliterated, as well as in the presence of pathological conditions such as odontogenic keratocysts, dentigerous cysts, adenomatoid odontogenic tumors, odontomas, or follicular space widening exceeding 5 mm. Additionally, distinguishing between a potential GD and normal alveolar bone resorption during physiological tooth eruption was possible.

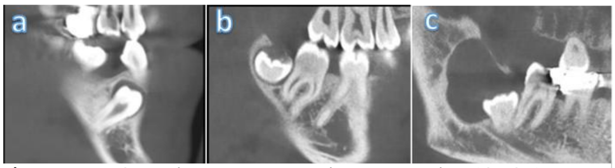

Figure 1.a. Cone beam computed tomography (CBCT) image showing absent for the gubernacular canal (GC) in unerupted permanent tooth. **b**. Cone beam computed tomography (CBCT) images showing an example of the present of a gubernacular canal (GC) in an unerupted permanent tooth**. c.** Cone beam computed tomography (CBCT) images showing an example of a enlarged gubernacular canal (GC) in an unerupted permanent tooth.

CBCT images were assessed using reformatted panoramic views as well as axial, sagittal, and coronal sections. GDs associated with impacted or unerupted teeth exhibiting pathology were classified as absent (0) (GD <1 mm) (Figure 1a), present (1) (GD 1–3 mm) (Figure 1b), or enlarged (2) (GD >5 mm) (Figure 1c) (3). In cases without

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as sociated pathology, GDs were categorized as absent (0), present (1), or enlarged (2).

Statistical analysis

The data were analyzed using IBM SPSS Version 23. Normality was assessed with the Kolmogorov-Smirnov and Shapiro-Wilk tests. The Mann-Whitney U test was employed for pairwise comparisons of non-normally distributed data, while the Kruskal-Wallis H test was used for comparisons involving three or more groups, followed by Dunn's test for multiple comparisons. Categorical data were analyzed using Pearson's Chi-Square test, with multiple comparisons evaluated through the Bonferroni-corrected Z test. Results are reported as frequency (percentage) for categorical variables and as mean ± standard deviation or median (minimum–maximum) for quantitative variables. A significance level of $p < 0.050$ was considered statistically significant.

RESULTS

After analyzing the images of 2,500 individuals, a total of 110 patients (53 females and 57 males) with pathology associated with impacted or unerupted teeth were included in the study group. Among these patients, 48.2% were female, while 51.8% were male. The control group consisted of 112 patients with impacted or unerupted teeth but without any associated pathology (57 females [50.9%] and 55 males [49.1%]). The distribution of the sample according to CBCT devices, age, gender and number of teeth is presented.

There was no statistically significant difference between the median age values according to the groups (p=0,355). The median age of the study group was found to be 21 and 16 in the control group (table 1).

Table 1. Comparison of age according to groups

	Mean ± S.Deviation	Median (Min-Max)	Test statistic	p*
Group				
Study	27,31 ± 17,69	21 (8 - 78)	5718	0,355
Control	22,57 ± 15,13	16 (8 - 70)		
Total	24,92 ± 16,58	16,5 (8 - 78)		

*Mann Whitney U test

Table 2. Age comparison by group

	Mean ± S.Deviation	Median (Min-Max)	Test statistic	p*
Presence of GD				
Absent	25,76 ± 18,7	16 (8 - 78)[b]	6,232	**0,044**
Present	23,01 ± 14,93	16 (8 - 70)[ab]		
Enlarged	30,35 ± 13,05	32 (11 - 54)[a]		
Total	24,77 ± 16,47	16 (8 - 78)		

*Kruskal Wallis H testi; [a-b]: There is no difference between groups with the same letter

No statistically significant difference in median age was observed between the study (median = 21 years) and control groups (median = 16 years; p = 0.355). However, age differed significantly based on gubernaculum dentis (GD) status (p = 0.044). The median age was 16 years for both absent and present GD cases but increased to 32 years in cases with enlarged GD, with a significant contrast between absent and enlarged GD subgroups (Table 2).

Table 3. Comparison of age by gender

	Mean ± S.Deviation	Median (Min-Max)	Test statistic	p*
Gender				
Female	25,37 ± 16,71	17 (8 - 78)	5672	0,307
Male	24,47 ± 16,52	16 (8 - 70)		
Total	24,92 ± 16,58	16,5 (8 - 78)		

*Mann Whitney U test

Gender distribution showed no significant age differences (median = 17 years for females vs. 16 years for males; p = 0.307). Females comprised 76.9% of the study group and 63.6% of the control group, while males constituted 23.1% and 36.4%, respectively. No significant association between gender and group allocation was identified (p = 0.686) (Table 3).

Table 4. Comparison of gender and gub according to groups

	Study	Control	Total	Test statistic	p*
Gender					
Female	53 (48,2)	57 (50,9)	110 (49,5)	0,163	0,686
Male	57 (51,8)	55 (49,1)	112 (50,5)		
GD					
Absent	59 (53,6)[a]	29 (26,1)[b]	88 (39,8)	53,242	**<0,001**
Present	31 (28,2)[a]	82 (73,9)[b]	113 (51,1)		
Enlarged	20 (18,2)[a]	0 (0)[b]	20 (9)		

* Pearson chi-square test; [a-b]: There is no difference between groups with the same letter.

GD status varied markedly between groups. In the study group, 53.6% exhibited absent GD, 28.2% present GD, and 18.2% enlarged GD. Conversely, the control group showed 26.1% absent GD and 73.9% present GD, with no enlarged GD cases. This distribution correlated strongly with group classification ($p < 0.001$) (Table 4).

Table 5. Comparison of GD according to gender

	Female	Male	Total	Test statistic	p*
GD					
Absent	44 (40,4)	44 (39,3)	88 (39,8)	0,168	0,919
Present	56 (51,4)	57 (50,9)	113 (51,1)		
Enlarged	9 (8,3)	11 (9,8)	20 (9)		

* Pearson chi-square test;

GD frequency by gender revealed similar patterns: 40.4% of females and 39.3% of males had absent GD, while 8.3% of females and 9.8% of males exhibited enlarged GD. No significant gender-based differences in GD status were observed (p = 0.919) (Table 5).

DISCUSSION

This study represents one of the few investigations to systematically evaluate the imaging characteristics of the gubernaculum dentis (GD) and its association with pathologies linked to impacted teeth. To our knowledge, it is the first to compare GD visualization between individuals with pathology-associated impacted/unerupted teeth and a demographically matched control group. By analyzing age- and gender-balanced cohorts differentiated by impacted dental status, we elucidated novel insights into GD's radiographic profile.

Anatomically, the GD traverses the alveolar bone, originating at the crest near the deciduous dentition (6). Historically, GD was described as a small, spherical radiolucency undetectable on conventional 2D radiographs (e.g., periapical or panoramic images). On CBCT and MDCT scans, GD appears as a continuous, corticated canal associated with the dental follicle of immature teeth. However, advanced 3D imaging modalities—notably CBCT and MDCT—now enable precise visualization of GD as a corticated, continuous canal adjacent to the dental follicle of developing teeth. CBCT, with its low radiation dose and high spatial resolution, has become indispensable for diagnosing craniofacial pathologies (10). According to current knowledge, gubernacular canals play a crucial role in normal tooth development. Radiological assessment of CBCT images, particularly in pediatric patients, plays a crucial role in the prognosis and treatment planning of unerupted or migrated teeth in mixed dentition and orthodontic cases (11). Therefore, GCs should be comprehensively evaluated during growth and development stages using advanced imaging modalities such as MDCT and CBCT. The dentist should be aware that tooth eruption may be abnormal if the gingival tissue surrounding the tooth is not visible on CBCT and MDCT or if it exhibits an angulation that deviates from the tooth axis. Oda et al. reported that delayed eruption teeth were less likely to present abnormal enamel development compared to normally erupted teeth. Additionally, impacted teeth in patients with delayed eruption were found to be significantly tilted along the tooth axis (8).

Nishida et al. (7), suggested that alterations in the GC may be indicative of anomalies in the eruption of permanent teeth. Similarly, studies conducted by Koç et al. and Gaeta-Araujo et al. reported lower detection rates of the GC in teeth exhibiting eruption disturbances (3)(12) In line with these findings, our study revealed that the GC was absent in 59 (53.6%) of impacted teeth associated with pathological conditions, compared to 29 (26.1%) of impacted teeth without any associated pathology. These results support the notion that pathological conditions may influence the radiographic visibility or development of the GC.

Gaeta-Arauja et al.(12) reported that horizontally positioned teeth with irregular eruption exhibited slightly higher GC detection rates compared to those in more favorable orientations (normal or angulated). It has been suggested that angular deviations in erupting teeth may interfere with or delay the resorption of the gubernacular dentis. Philipsen et al. (13) proposed that the GC and GCo may play a role in the development of AOT, as 80% of AOT cases occur in the region between the permanent incisors and canines, where these structures are typically located. Hodson (14).. hypothesized that the absence of GCo in the deciduous dentition may explain the rarity of AOT in association with primary teeth. However, Ide et al. (6) questioned the validity of this hypothesis, noting that 4% of pericoronary lesions with AOT in permanent teeth were observed even in the absence of both GCo and GC. Saya et al(15). presented a case of ameloblastic fibro-odontoma (AFO) located in the left mandibular second molar region of an 8-year-old patient. CBCT revealed a spatial relationship between the lesion and the gubernacular dentis of the unerupted second molar tooth. In our study, the exact nature of the associated pathologies could not be determined due to the absence of histopathological reports. However, a follicular space wider than 5 mm has been linked to delayed tooth eruption in the literature, and may serve as a radiographic indicator of underlying pathological conditions. Collectively, the findings of these studies support our hypothesis that pathological conditions may influence the presence or radiographic visibility of the gubernacular dentis. The findings of these studies support our hypothesis that pathological conditions may influence the presence or radiographic visibility of the gubernacular dentis.

Historically, GD has been implicated in ameloblastoma pathogenesis. Contemporary studies further associate GD with odontogenic tumors (e.g., odontomas, adenomatoid odontogenic tumors) and cysts (e.g., odontogenic keratocysts [OKC], dentigerous cysts) (16)(17). However, the hypothesis that GD may serve as an origin for such lesions remains understudied, partly due to limited research and diagnostic constraints. Notably, the absence of GD in 53.6% of pathology-associated cases in our cohort underscores its potential role in odontogenic mass development. The frequency of GD presence was notable (73.9%) in the pathology-free control group, with no cases of GD enlargement (0%). These findings align with existing literature suggesting a potential link between GD and odontogenic tumors and cysts. Further investigations utilizing advanced imaging and molecular techniques are warranted to validate these observations.

Rizeli et al.(11) investigated normally erupting permanent teeth in tomographic images of pediatric patients during the mixed dentition period and reported a GC prevalence of 73.5%. Despite differences in age groups, this prevalence is notably similar to the rate observed in our control group (73.9%). Liu et al.(18) evaluated the presence of the GC in mandibular canine teeth of pediatric patients and found it to be present in all cases, indicating a high detection rate in this specific region and age group. Behrouzi et al. (19)examined a patient cohort consisting of both adult and pediatric individuals. They reported a GC prevalence of 92.1% in normally erupted teeth, which is considerably higher than that found in our study group. In impacted teeth, the prevalence was 82.9%, again higher than in our findings. However, for delayed erupted teeth, their reported prevalence of 75% was similar to that observed in our study. While the aforementioned studies have explored various parameters such as the presence, shape, size, volume, and angle of the GC, none have specifically addressed the relationship between GC presence and the existence of associated pathology, which represents a distinctive focus of our study.

Ugurlu et al. (20) reported no significant difference in GD incidence among study participants of different ages. Additionally, there was no significant difference between male and female participants regarding GD incidence, with the sample population demonstrating statistical homogeneity in terms of gender and age. Our results align with the literature, as we found a high incidence of GD in pathology-related impacted teeth in both the study and control groups.

No statistically significant differences in GD status or gender distribution were observed between the study and control groups ($p > 0.05$). However, a significant age-related disparity in GD status was identified ($p = 0.044$). Individuals with absent GD exhibited a higher median age (32 years) compared to those with present GD (16 years), while cases of GD enlargement showed intermediate age values. This finding aligns with Koç et al.(3) who reported reduced GCo detection rates in older age groups, particularly noting higher GC visibility in individuals aged ⩽ 12 years. Notably, neither study identified gender-based variations in GD/GC status. The distinct age stratification between subgroups — specifically, the contrast between absent GD (older cohort) and present GD (younger cohort)—suggests age-dependent regression or remodeling of the gubernacular structure. Gupta et al.(21),identified gubernacular tracts exclusively in odontogenic lesions—including ameloblastoma, odontoma, and odontogenic keratocysts—but not in non-odontogenic pathologies (e.g., aneurysmal bone cyst, central giant cell granuloma). This association was independent of lesion size or jaw location. Oda et al. (22). further corroborated this distinction, noting that GTs in odontogenic tumors/cysts frequently appear on MDCT as low-density, corticated tracts near the alveolar crest or superior tumor margins. In contrast, non-odontogenic masses lacked GT continuity, underscoring GT's specificity to odontogenic pathogenesis.

This study has several limitations. First, its retrospective design relied solely on radiological assessments to evaluate the presence and features of the GD, without histopathological confirmation. Consequently, the nature of the associated pathologies could not be definitively identified. Additionally, no distinction was made between impacted and unerupted teeth, which may influence the interpretation of the findings. The potential misinterpretation of an enlarged GD in the presence of pathology should also be considered, as it may affect diagnostic accuracy.

Intraobserver agreement was established through consensus rather than statistical evaluation. While this approach ensured consistency, future studies would benefit from using quantitative methods to assess intraobserver reliability, thereby enhancing scientific rigor. Furthermore, no a priori power analysis was conducted for this study. As the primary aim was to investigate the association between impacted or unerupted teeth and potential pathologies, the lack of a predetermined sample size calculation represents a methodological limitation that may affect the statistical power and generalizability of the results

CONCLUSION

A inverted correlation was observed between the presence of pathology associated with impacted or unerupted teeth and the presence of the GD. The high incidence of GD in cases with pathology related to impacted or unerupted teeth suggests a potential relationship between GD and these pathologies. However, further studies incorporating histopathological evaluations are necessary to validate these findings.

Acknowledgments
None

Authorship contributions
ZO was responsible for conceptualization, while both OBD and ZO contributed to data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resource management, software handling, supervision, validation, and visualization. Additionally, they both participated in writing the original draft and reviewing/editing the manuscript.

Data availibity statement
Data available on request.

Declaration of competing interest
The authors declare that there is no conflict of interest.

Ethics
Ethics committee approval was obtained with the decision of Çankırı Karatekin University Health Sciences Ethics Committee dated 13.11.2023.

Funding
This study was not funded by any institution or organization.

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