



Radiographic Features of the Gubernaculum Tract in Impacted Teeth

Samareh Mortazavi ¹, Mahrokh Imanimoghaddam ¹, Arefeh Delkhosh ², Amirhosein Kordi Karimabadi ^{1*}, Toktam Pourebrahim ¹

1. Department of Oral and Maxillofacial Radiology, School of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran.
2. Private Practice, Mashhad, Iran.

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*Corresponding author:
Amirhosein Kordi Karimabadi

Department of Oral and Maxillofacial Radiology,
School of Dentistry, Mashhad University of Medical
Sciences, Mashhad, Iran.

Tel: +98-938-4074331
Fax: +98-21-84903747
Email: a.kordi4331@gmail.com

ABSTRACT

Introduction: The gubernaculum tract (GT) is a fibrous canal extending from the dental follicle to the alveolar crest, playing a crucial role in tooth eruption. This structure is not visible on conventional radiographs but can be reliably detected using cone-beam computed tomography (CBCT). This study aimed to evaluate the radiographic characteristics of the GT in impacted teeth using CBCT imaging.

Materials and Methods: In this cross-sectional study, CBCT scans of 85 patients (41 males, 44 females) with impacted teeth, referred to Mashhad Dental School between December 2020 and December 2022, were evaluated. The mean age was 21.4 ± 11.06 years (range: 8–48 years). The presence, dimensions, morphology, and attachment patterns of the GT were assessed in coronal and sagittal planes. Data were analyzed using Chi-square and Mann-Whitney U tests ($\alpha = 0.05$).

Results: The GT was detectable in 36.7% of impacted teeth, with significantly higher visibility in males ($P = 0.015$). Canines were the most commonly affected teeth. The most frequent causes of impaction were abnormal eruption angle and tooth displacement. The GT most commonly showed central attachment in mesio-distal (64%) and bucco-lingual (76%) dimensions and occlusal attachment in the occluso-cervical direction (52%). Rectangular morphology was predominant (57%). Mean GT length and width were approximately 3.1–3.3 mm in both planes.

Conclusion: CBCT enables detailed visualization of the gubernaculum tract in impacted teeth. The presence and characteristics of the GT may serve as predictive indicators for eruption disturbances and assist in treatment planning decisions.

Keywords: Cone-beam computed tomography; Tooth; Impacted; Tooth eruption; Gubernaculum dentis; Dental follicle.

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Introduction

Tooth eruption is a complex, highly regulated process that guides the tooth from its developmental position within the alveolar bone to its functional occlusion. The gubernaculum dentis, also referred to as the gubernacular cord, is a fibrous structure containing remnants of the dental lamina that extends from the dental follicle to the oral mucosa. It is believed to play a critical role in guiding the eruptive pathway by inducing localized bone resorption through the secretion of chemotactic factors, such as epidermal growth factor (EGF) and colony-stimulating factor-1 (CSF-1) [1,2]. The radiolucent canal formed around this cord is known as the gubernaculum tract (GT).

The GT was originally described as a structure associated with successional teeth, located lingually to deciduous teeth. However, recent studies have demonstrated its presence in permanent molars without predecessors, supernumerary teeth (e.g., mesiodens), and even in some odontogenic cysts and tumors [3-7]. Alterations in the course, diameter, or visibility of the GT have been linked to disturbances in tooth eruption, leading to impaction [8,9]. Tooth impaction is a common clinical condition, particularly affecting maxillary and mandibular canines and second premolars. It may result in malocclusion, root resorption of adjacent teeth, cystic degeneration, and increased risk of infection [10-12]. Conventional two-dimensional radiographs (panoramic and periapical) often fail to demonstrate the GT due to its small diameter (1-3 mm) and superimposition of anatomical structures [13]. Cone-beam computed tomography (CBCT), introduced in 1998, has revolutionized maxillofacial imaging by providing high-resolution three-dimensional visualization with significantly lower radiation doses compared to medical-grade CT [14,15].

CBCT enables precise evaluation of the GT in terms of presence, dimensions, morphology, attachment patterns, and its relationship with surrounding anatomical structures [16-18]. Despite growing interest in the GT as a potential predictor of eruption disturbances, limited data are available regarding its radiographic characteristics in impacted permanent teeth, particularly in the Iranian population. To the best of our knowledge, no previous study has systematically evaluated GT visibility, dimensions, and morphology in a relatively large sample of impacted teeth using CBCT. Therefore, the present study aimed to evaluate the radiographic features of the gubernaculum tract in impacted per-

manent teeth using cone-beam computed tomography.

Materials and Methods

This cross-sectional descriptive study was approved by the Ethics Committee of Mashhad University of Medical Sciences (Ethical code: IR.MUMS.DENTISTRY.REC.1401.14). CBCT archives of patients referred to the Department of Oral and Maxillofacial Radiology, Mashhad Dental School, between December 2020 and January 2023 were reviewed. Inclusion criteria were: permanent teeth with complete root formation confirmed as impacted on CBCT. Exclusion criteria comprised history of maxillofacial trauma or surgery, syndromic conditions affecting tooth eruption (e.g., cleidocranial dysplasia, Gardner syndrome), and presence of cleft lip/palate. All images were acquired using a Planmeca ProMax 3D Classic unit (Planmeca, Helsinki, Finland) with a voxel size of 160 μm , 90 kVp, 10 mA, exposure time 12 s, and field of view 8 \times 8 cm. Multiplanar reconstructions (axial, sagittal, and coronal) were evaluated using Planmeca Romexis Viewer software (version 6.0.0.3) by a single experienced oral and maxillofacial radiologist.

The following variables were recorded:

- Demographic data (age, sex).
- Location (maxilla/mandible, tooth type).
- Cause of impaction (improper eruption angle, displacement/malposition, supernumerary teeth, dilaceration, odontoma, no obvious cause).
- Associated pathology (normal follicle, enlarged follicle > 2.5 mm, cyst/tumor)
- Presence/absence of gubernaculum tract (GT).
- GT morphology (straight, rectangular, curved, bending, contracted).
- GT attachment to alveolar crest (buccal, central, lingual, incisive canal).
- GT attachment to dental follicle in three dimensions: –Occluso-cervical (occlusal, central, cervical)–Mesio-distal (mesial, central, distal)–Bucco-lingual (buccal, central, lingual).
- GT length (distance from dental follicle to alveolar crest opening) and maximum width in coronal and sagittal planes.

In cases with odontoma, only GT presence/absence was recorded; measurements of dimensions, shape, and

attachment sites were excluded due to distortion by the lesion.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 25 (IBM, Armonk, NY, USA). Categorical variables were compared using the Chi-square test, while continuous variables were analyzed with the Mann-Whitney U test. P-values < 0.05 were considered statistically significant.

Results

A total of 85 impacted permanent teeth from 85 patients (41 males, 48.2%; 44 females, 51.8%) were evaluated. The mean age was 21.4 ± 11.06 years (range 8–48 years). Fifty-three teeth (62.4%) were in the maxilla and 32 (37.6%) in the mandible. The most commonly impacted teeth were canines (35.3%), followed by central incisors, premolars (both 21.2%), third molars (18.8%), and mesiodens (3.5%). The leading causes of impaction were improper eruption angle (32.9%) and displacement/malposition (27.1%). Pathological conditions were observed in 11.8% of cases (enlarged follicle

4.7%, cyst/tumor 7.1%) (Table 1). The gubernaculum tract (GT) was visible in 32 teeth (37.6%). Visibility was significantly higher in males (51.2%) than in females (25.0%) ($P = 0.015$). No significant association was found between GT visibility and age ($P = 0.935$), jaw ($P = 0.302$), or tooth type ($P = 0.302$), although the highest visibility was observed in third molars (56.2%). After excluding odontoma cases and teeth opening into the incisive canal, detailed GT analysis was performed on 25 teeth.

Attachment to the dental follicle was most frequently occlusal (52%), central in mesio-distal (64%) and bucco-lingual (76%) dimensions (Table 2). The GT opened most commonly to the lingual alveolar crest (62.1%), followed by central (17.2%), buccal (6.9%), and incisive canal (13.8%). The most prevalent GT morphology was rectangular (48%), followed by straight (32%), contracted (12%), and curved (8%). No bending morphology was observed (Table 3). Mean GT length was 3.27 ± 1.82 mm (coronal) and 3.11 ± 1.77 mm (sagittal); mean width was 3.31 ± 2.47 mm (coronal) and 3.12 ± 2.29 mm (sagittal) (Table 4).

Table 1. Frequency of impacted teeth, causes of impaction, and associated pathology (n = 85).

Category	Details	Frequency	Percentage
Type of Impacted Teeth	Canine	30	35.3%
	Central incisor	18	21.2%
	Premolar	18	21.2%
	Third molar	16	18.8%
	Mesiodens	3	3.5%
Causes of Impaction	Improper eruption angle	28	32.9%
	Displacement/malposition	23	27.1%
	Supernumerary teeth	9	10.6%
	Odontoma	5	5.9%
	Dilaceration	1	1.2%
Associated Pathology	No obvious cause	19	22.4%
	Enlarged follicle (>2.5 mm)	4	4.7%
	Cyst/tumor	6	7.1%
	No pathology	75	88.2%

Table 2. Attachment site of the gubernaculum tract to the dental follicle in three dimensions (n = 25).

Dimension	Attachment Site	Frequency	Percentage
Occluso-cervical	Occlusal	13	52.0%
	Central	7	28.0%
	Cervical	5	20.0%
Mesio-distal	Central	16	64.0%
	Distal	7	28.0%

Dimension	Attachment Site	Frequency	Percentage
Bucco-lingual	Mesial	2	8.0%
	Central	19	76.0%
	Buccal	4	16.0%
	Lingual	2	8.0%

Table 3. Morphology of the gubernaculum tract (n = 25).

Morphology	Frequency	Percentage
Rectangular	12	48.0%
Straight	8	32.0%
Contracted	3	12.0%
Curved	2	8.0%
Bending	0	0.0%

Table 4. Length and width of the gubernaculum tract in coronal and sagittal planes (n = 25).

Measurement	Plane	Minimum (mm)	Maximum (mm)	Mean±SD (mm)
Length	Coronal	0.77	9.55	3.27±1.82
	Sagittal	1.01	10.00	3.11±1.77
Width	Coronal	0.45	8.91	3.31±2.47
	Sagittal	0.32	8.16	3.12±2.29

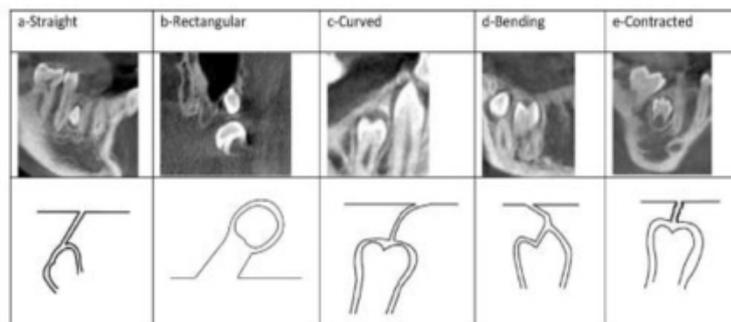


Figure 1. Schematic image of the gubernaculum canal in CBCT images.

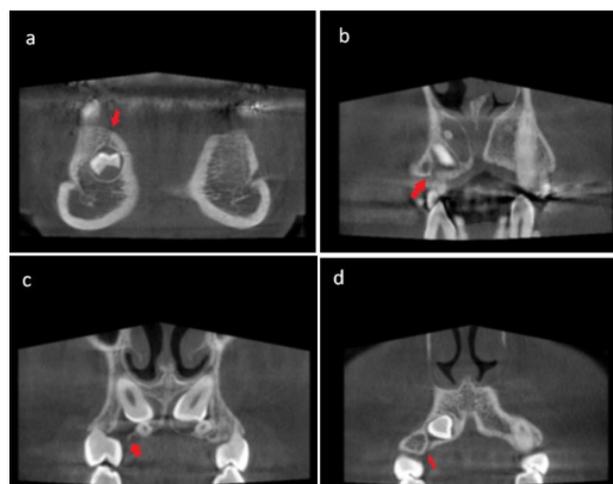


Figure 2. Coronal sections of gubernaculum canal: A: Contacted. B: Curved. C: Rectangular. D: Straight.

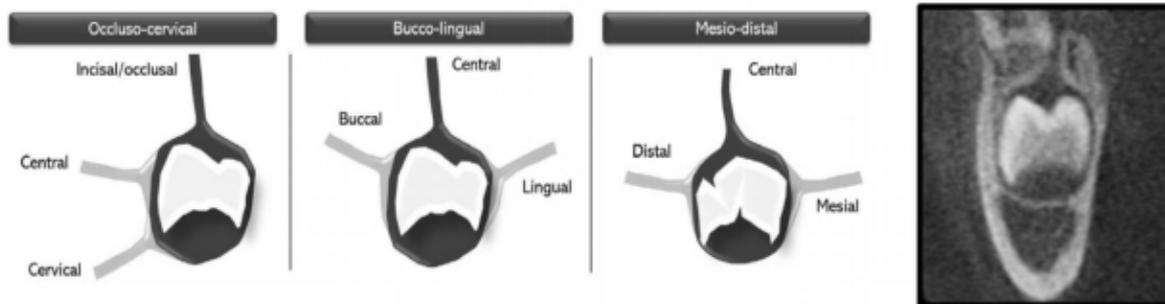


Figure 3. Connection site of the gubernaculum tract to the dental follicle.

Discussion

The gubernaculum tract (GT) is increasingly recognized as an important radiographic landmark in tooth eruption. The present CBCT-based study evaluated its visibility, morphology, dimensions, and attachment patterns in 85 impacted permanent teeth. The overall GT detection rate was 37.6%, which is lower than most previous reports. Oda et al. [22] observed GT in 50–83% of various impacted anterior teeth, Koc et al. [23] reported 83%, and Gaeta-Araujo et al. [24] found rates of 62.9–90.6% depending on eruption status. The lower visibility in our sample may be attributed to several factors: inclusion of all tooth types (including third molars and supernumeraries), older mean patient age (21.4 years), and strict criteria for GT identification. Mature root formation and prolonged impaction may lead to partial or complete obliteration of the GT through progressive bone deposition.

A significant gender difference was observed, with GT more frequently visible in males (51.2% vs. 25.0%, $P = 0.015$). To our knowledge, this is the first study to report such an association in impacted permanent teeth, warranting further investigation. Rectangular (48%) and straight (32%) were the most common morphologies, differing from Zengin et al. [25], who found straight morphology predominant in supernumerary teeth. Attachment to the dental follicle was most frequently occlusal (52%) and central in mesio-distal (64%) and bucco-lingual (76%) dimensions, whereas opening into the alveolar crest was predominantly lingual/palatal (62.1%). These findings are largely consistent with previous reports [24,25] and support the role of GT as a relatively conserved eruption pathway even in impacted teeth. Mean GT length (3.1–3.3 mm) and width (3.1–3.3 mm) were similar in coronal and sagittal planes, confirming symmetrical development of this structure. These dimensions align closely with values reported in normally erupting and impacted teeth in other populations [22–25]. The presence of GT in five

teeth associated with odontoma reinforces its potential utility in differentiating odontogenic from non-odontogenic lesions, as previously suggested [26]. Study limitations include the relatively older patient cohort, the absence of a control group of normally erupting teeth, and a limited number of certain tooth types. Future studies with larger samples, younger age groups, and direct comparison between impacted and normally erupting teeth are recommended.

Conclusion

The present CBCT study demonstrates that the gubernaculum tract can be identified in approximately 37.6% of impacted permanent teeth, a significantly lower visibility compared to normally erupting teeth reported in the literature. The absence or alteration of this structure may therefore serve as a potential radiographic indicator of disturbed eruption patterns. Although no significant association was found between GT visibility and age or jaw, a notable gender difference was observed, with higher detection rates in males ($P = 0.015$), representing a novel finding that warrants further investigation in larger cohorts. The most frequent GT morphology was rectangular, with predominant occlusal attachment to the dental follicle and lingual/palatal opening into the alveolar crest.

Dimensional analysis revealed consistent mean values of approximately 3.1–3.3 mm in both length and width across coronal and sagittal planes. These findings highlight the clinical value of CBCT in detailed assessment of the gubernaculum tract and suggest that its radiographic characteristics may aid in predicting eruption behavior, differentiating pathological conditions, and improving treatment planning for impacted teeth. Further prospective studies comparing impacted and normally erupting teeth in younger populations are recommended to validate and expand on these observations.

Conflict of Interest

There is no conflict of interest to declare.

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