International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(Review Article)

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Anatomy and morphology of the anus: A review of the form and function of the anal canal

Alina Walbrun *

Division of Hand, Plastic and Aesthetic Surgery, University Hospital, LMU Munich, Germany.

International Journal of Science and Research Archive, 2026, 20(01), 754–762

Publication history: Received on 15 June 2026; revised on 20 July 2026; accepted on 23 July 2026

Article DOI: https://doi.org/10.30574/ijsra.2026.20.1.1523

Abstract

Background/Objective: Despite its small size, the anus is an anatomically complex structure whose characteristic shape results from the interplay of embryological zonation, layered musculature, and specialised vascular cushions. This narrative review aims to systematically summarise the anatomical basis of normal anal form and function, from embryological development to clinical relevance.

Methods: A structured, non-systematic literature search was conducted across PubMed/PMC, StatPearls, and other peer-reviewed and educational anatomical resources, focusing on English-language sources describing the embryology, gross anatomy, musculature, vascular anatomy, and normal variability of the anal canal, searched through July 2026.

Results: The anal canal develops from two embryologically distinct compartments – the endodermal hindgut and the ectodermal proctodeum – joined at the dentate line. Continence and shape are maintained by a three-layered muscular system (internal anal sphincter [IAS], external anal sphincter [EAS], and puborectalis muscle) that generates the anorectal angle, together with three vascular anal cushions that provide fine continence and contribute to the characteristic radial “rosette” pattern of the closed anus. The macroscopic architecture is largely conserved between individuals, while length, crypt number, and cushion distribution show normal variability.

Conclusion: The form of the anus reflects a coordinated anatomical system rather than a simple opening. Distinguishing this conserved basic plan from normal individual variability is relevant both for clinical practice and for general anatomical understanding of a frequently stigmatised body region.

Keywords: Anal canal; Anatomy; Anal sphincter complex; Dentate line; Anal cushions; Anorectal angle

1. Introduction

In public perception, the anus is often reduced to its function as a simple ‘opening’. From an anatomical perspective, however, it is a highly differentiated organ composed of tissues of different embryological origin, possessing three functionally distinct muscular layers, and equipped with specialised vascular structures that allow fine-tuning of continence. The anal canal performs several tasks simultaneously: it acts as a mechanical barrier against the entry of pathogens, enables sensory discrimination between solid, liquid, and gaseous rectal contents, and ensures both voluntary and involuntary control of defecation [1].

The aim of this review is to systematically present the anatomical basis that determines the form of the anus in the healthy state – from embryological development, through macroscopic organisation and musculature, to the vascular cushions and the resulting external morphology. Normal interindividual variability and selected clinical correlates of

* Corresponding author: Alina Walbrun

this anatomical knowledge are discussed at the end. Pathological changes (e.g. haemorrhoidal disease, fissures) are addressed only to the extent that they aid understanding of normal anatomy.

2. Materials and Methods

This is a narrative literature review; it does not involve original experimental work, and no studies were performed on human participants or animals by the author. Anatomical, embryological, and clinically oriented literature was identified through structured searches of PubMed/PMC, StatPearls, and Google Scholar, together with relevant institutional and society sources (e.g. University of California San Francisco Anal Neoplasia Clinic, Research and Education Center; Annals of Gastroenterology; Gastroenterology Clinics of North America), searched through July 2026. Where available, peer-reviewed primary or secondary literature was prioritised over tertiary educational summaries.

Search terms included combinations of 'anal canal anatomy', 'dentate line', 'anal sphincter', 'puborectalis muscle', 'anorectal angle', 'proctodeum embryology', 'cloaca development', and 'hemorrhoidal cushion anatomy'. English-language sources describing the gross, functional, histological, or embryological anatomy of the anal canal, or the anatomical basis of anal continence, were included; sources concerned exclusively with disease management were excluded unless they also provided anatomical or physiological data relevant to normal structure. Reference lists of retrieved sources were hand-searched for additional relevant material. Given the descriptive, narrative scope of this review, no formal systematic quality appraisal or meta-analysis was undertaken; findings were synthesised thematically. As a narrative rather than systematic review, this work is subject to selection bias in source identification, and several quantitative estimates cited below (e.g. sphincter pressure contributions, cushion distribution frequencies) derive from single studies with limited sample sizes; these figures should be read as illustrative rather than definitive.

3. Results and Discussion

3.1. Embryological Development

The characteristic two-part form of the anal canal can only be understood against the background of its embryological origin. From the fourth week of development, the hindgut opens into the cloaca, an endodermally lined cavity that communicates ventrally with the umbilical cord via the allantois and is bounded caudally by the cloacal membrane – a junctional layer of endoderm and ectoderm without intervening mesoderm [2, 15].

Between the fourth and eighth weeks, the urorectal septum, a mesodermal ridge of tissue, grows in a craniocaudal direction between the hindgut and allantois toward the cloacal membrane, progressively dividing the cloaca into a ventral compartment (urogenital sinus) and a dorsal compartment (anorectal canal) [2, 15]. Around the seventh to eighth week the septum reaches the cloacal membrane and fuses with it; the site of fusion later forms the perineal body. This division also splits the cloacal membrane into an anterior urogenital membrane and a posterior anal membrane [16].

Around the ninth week, the surrounding mesenchyme proliferates around the anal membrane, raising the overlying ectoderm into a shallow pit – the proctodeum (anal pit). The anal membrane ruptures toward the end of the embryonic period, establishing continuity between the upper, endodermally lined portion and the lower, ectodermally lined portion of the anal canal [16].

This dual embryological origin has far-reaching consequences for mature anatomy: the upper two-thirds of the anal canal derive from the hindgut and are of endodermal origin, while the lower third derives from the proctodeum and is of ectodermal origin. The boundary between the two segments marks the dentate line (pectinate line) in the mature organ – a boundary that affects not only histology but also innervation, arterial supply, venous drainage, and lymphatic drainage [2, 1]. From its earliest development, the anus is therefore not a uniform tube but the fusion of two developmentally distinct compartments – a fact that is fundamental to understanding its form.

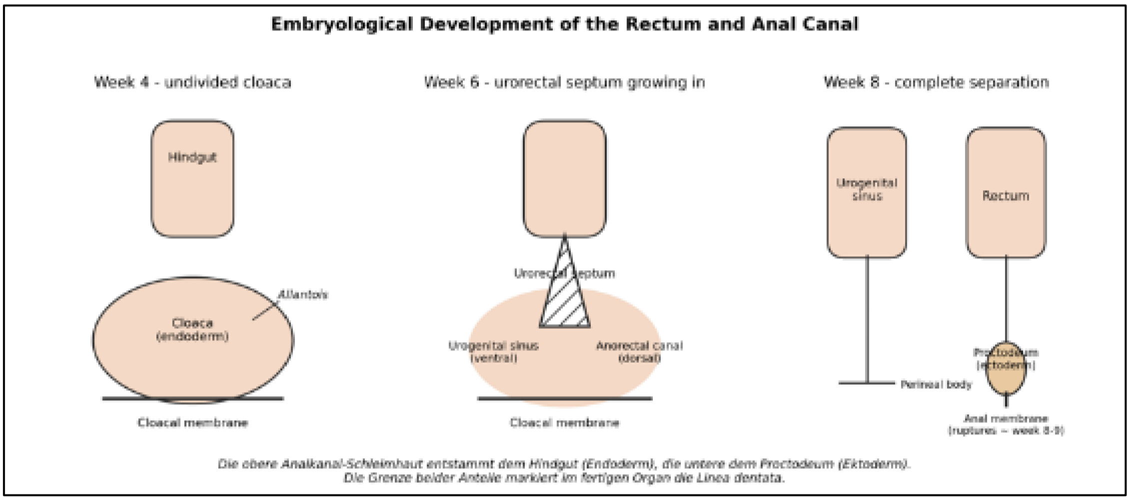

Figure 1 Embryological development of the rectum and anal canal (original illustration)

3.2. Macroscopic Anatomy and Zonation

Strictly speaking, the term ‘anus’ refers only to the external opening of the digestive tract, whereas the ‘anal canal’ describes the wholly extraperitoneal canal behind it. Two different definitions are used in the literature: the anatomical anal canal extends from the anal verge to the dentate line and is comparatively short, averaging 2.5 to 4 cm. The surgical anal canal – the definition more commonly used in clinical practice – extends from the anal verge to the palpable anorectal ring, formed by the external anal sphincter and the puborectalis muscle, and measures approximately 4 cm on average [1, 5]. The anal canal lies entirely within the anal triangle of the perineum and is flanked bilaterally by the ischioanal fossae [3].

The dentate line (also called the pectinate line) is a circumferentially running, serrated line that divides the anal canal into an upper (two-thirds) and a lower (one-third) segment. It is formed by the saw-toothed lower margin of the anal valves and simultaneously marks the embryological boundary between endodermal and ectodermal tissue [1]. Three mucosal zones can be distinguished along the anal canal [1, 6]:

The **columnar zone** lies above the dentate line, is lined by simple columnar epithelium, and derives from the hindgut. It is predominantly innervated autonomically (viscerally) and is therefore largely insensitive to pain, temperature, and touch, although it does register stretch [6, 1].

The **transitional zone** (also called the pecten) is a narrow band immediately surrounding the dentate line, in which transitional epithelium gradually converts the columnar epithelium into stratified squamous epithelium [1].

The **cutaneous zone** (anoderm) lies below the dentate line, is covered by non-keratinised stratified squamous epithelium, and is of ectodermal origin. Unlike the true perianal skin beyond the anal verge, the anoderm lacks skin appendages such as hair follicles or sebaceous glands [5, 6]. Because this zone is somatically innervated – via branches of the pudendal nerve – it is, unlike the columnar zone, highly sensitive to pain, touch, and temperature, which is of considerable clinical importance in conditions such as anal fissure [4, 6].

Immediately proximal to the dentate line, the mucosa is thrown into longitudinal folds, the anal columns (columns of Morgagni). This folding allows the anal canal to expand radially during defecation without tissue tearing. At the base of each column, the mucosal folds form the anal valves already mentioned, in whose recesses a variable number (typically four to twelve) of anal crypts are found. These crypts represent the openings of the anal (proctodeal) glands and are of clinical relevance, since infections originating from them can lead to anal abscesses and fistulae [12]. This finely folded microarchitecture is thus not merely a passive anatomical detail but actively contributes to the distensibility and function of the canal.

3.3. The Sphincter Complex

The form of the anal canal is substantially determined by a three-part muscular apparatus that produces the characteristic closure both at rest and during contraction.

The **internal anal sphincter (IAS)** is the direct cranial continuation of the circular smooth muscle layer of the rectum. It is involuntarily innervated, under sympathetic control, and is considered by most of the literature to provide the largest share of resting tone in the anal canal – estimates range from approximately 70 to 80 percent of resting anal pressure [22, 8]. On endoanal ultrasound it appears as a uniformly hypoechoic ring approximately 1.5 to 4 millimetres thick [24].

The **external anal sphincter (EAS)** surrounds the internal sphincter as a striated, voluntarily innervated muscular cuff. It is classically described in three parts – subcutaneous, superficial, and deep – the deep part merging directly with the puborectalis muscle [8, 24]. It is innervated via the inferior rectal nerve, a branch of the pudendal nerve [22], measures approximately 7.7 to 8.6 millimetres on endoanal ultrasound [24], and allows a rapid, though not sustainable, voluntary increase in tone – for example in response to sudden urgency or increased intra-abdominal pressure. The muscle fatigues under prolonged load [13].

The **puborectalis muscle** is part of the pelvic floor (levator ani) and forms a U-shaped sling that wraps around the anal canal posteriorly and pulls it toward the pubic symphysis. It is in a state of continuous tonic activity, even during sleep, and together with the external anal sphincter forms a closely coupled functional unit [8, 9]. This ventrally directed pull creates the anorectal angle, reported at approximately 90 to 110 degrees at rest; the angle sharpens further during voluntary squeeze and becomes more obtuse as the pelvic floor descends and the anal canal opens and shortens during defecation [10, 13].

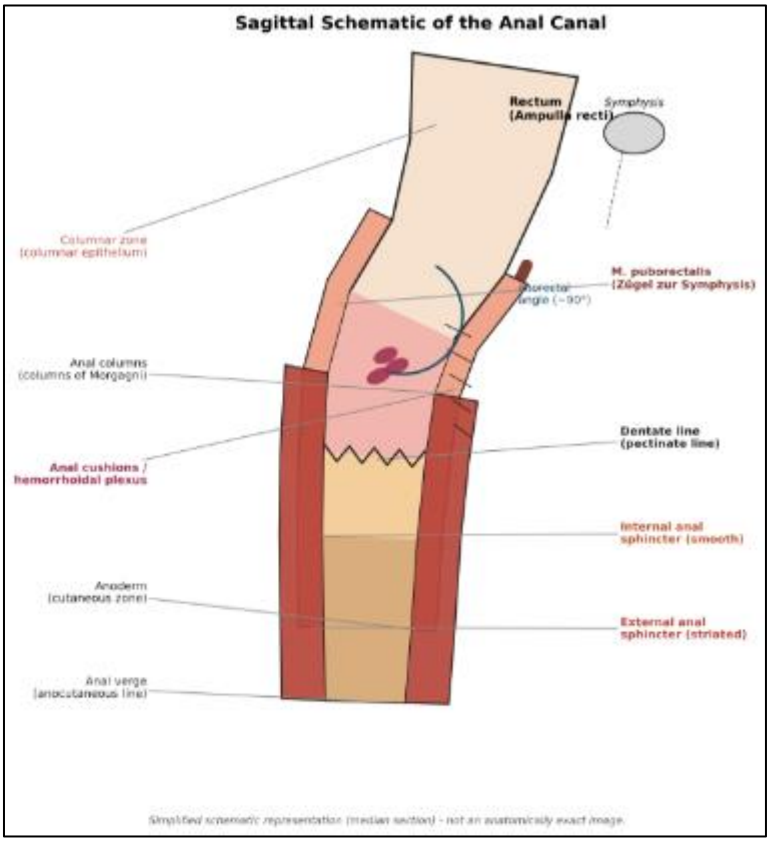

Figure 2 Sagittal schematic of the anal canal, showing the sphincter complex, dentate line, and anal cushions (original illustration)

This angle is regarded as a central component of one of the classic continence models, the so-called 'flap-valve' theory: a rise in intra-abdominal pressure presses the anterior rectal wall against the angulated canal, providing additional closure. This theory is not undisputed in the literature; other work attributes continence more strongly to the pressure gradient between rectum and anal canal and to the activity of the external sphincter and puborectalis, noting that the anorectal angle does not necessarily change substantially after successful sphincter reconstruction [13]. Regardless of the precise weighting of the mechanisms involved, the integrity of the puborectalis muscle is considered essential: its division results in substantially more severe incontinence than isolated division of the internal or external sphincter [8, 9].

Functionally closely linked to the sphincter complex is the longitudinal muscle (conjoined longitudinal muscle), which arises from the continuation of the rectal longitudinal muscle together with fibres of the levator ani, runs between the internal and external sphincters, and finally fans out as the corrugator cutis ani muscle in the perianal skin [7]. This structure largely explains the radial fold pattern of the external anal skin described in section 3.5.

3.4. Anal Cushions (Corpus Cavernosum Recti)

Above the dentate line lie three discrete, submucosal vascular cushions, classically described in the literature at three fixed positions: left lateral, right posterior, and right anterior, corresponding to the 3, 7, and 11 o'clock positions in the lithotomy position (12 o'clock = ventral) [17, 18, 21]. Histologically, these cushions consist of direct arteriovenous connections (sinusoids) without an intervening capillary bed, smooth muscle (Treitz's muscle), and connective tissue (Park's ligament) that fixes the cushions in position [14]. The absence of a capillary passage also explains why bleeding from this tissue – for example in haemorrhoidal disease – appears bright red and arterial in character [14, 20].

Functionally, the anal cushions fill with arterial blood at rest and thereby contribute to a complete, airtight closure of the anal canal that goes beyond muscular contraction alone, in particular enabling fine continence for gas and liquid [17]. During defecation they empty, as the internal anal sphincter relaxes and venous outflow increases, allowing stool to pass through the canal without tissue resistance [17]. Their contribution to resting anal pressure has been estimated at approximately 15 to 20 percent, although the precise figure is likely to depend on measurement method [19].

Importantly for understanding health and disease in this region, the anal cushions are not a pathological structure but an integral, functionally necessary part of normal anatomy. Only their excessive enlargement, downward displacement, or prolapse are termed haemorrhoids and thereby constitute disease [11, 20].

3.5. External Form: The Perianal "Rosette"

The externally visible form of the closed anus is not a passive, slit-like opening but the active result of the muscular interplay described above. The tonic pull of the corrugator cutis ani muscle, together with the resting tone of the sphincters, gathers the squamous anal skin into radially arranged folds that converge in a star-like pattern on a central point. This characteristic fold pattern is sometimes described as a 'rosette' shape.

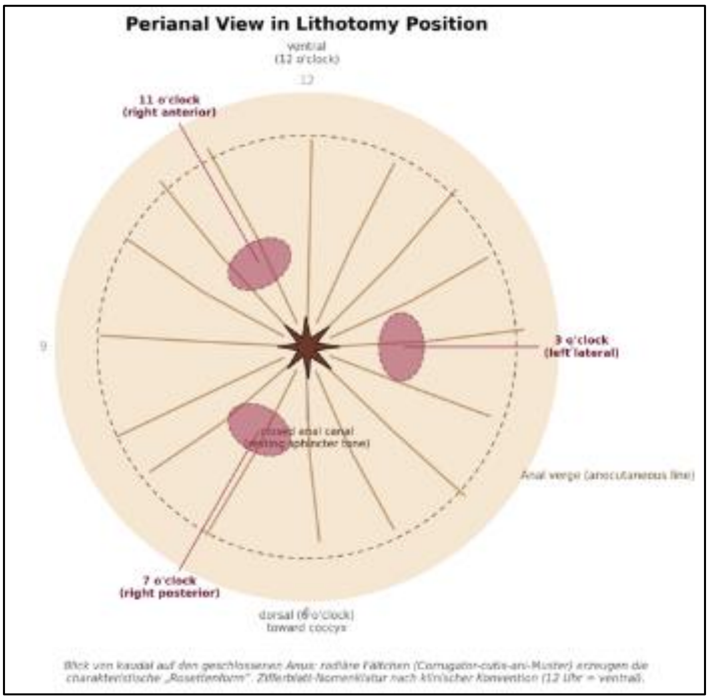

Figure 3a Perianal view in the lithotomy position, showing radial folding and the position of the anal cushions (original illustration)

This actively maintained folding is functionally significant: it increases the contact area of the apposed tissue surfaces compared with a smooth, circular closure, thereby contributing additionally to sealing. The form and regularity of this fold pattern vary – as discussed in section 3.6 – between individuals and can be influenced by factors such as skin elasticity, prior vaginal delivery, or age-related connective tissue changes. A markedly flattened, irregular, or asymmetric fold pattern may, by contrast, be a clinical indicator of functional or structural change, for example in the context of neurogenic continence disorders or after previous surgery.

Figure 3B Clinical photograph of the external anal region in the lithotomy position, overview

Figure 3C Clinical photograph of the external anal region in the lithotomy position, detail view

3.6. Individual Variability

The anatomical literature describes the basic macroscopic architecture of the anal canal as comparatively constant – marked anatomical variants are rarely documented [4]. At a finer structural level, however, notable individual variability is apparent:

- **Length:** The anatomical anal canal is reported as 2.5 to 4 cm, occasionally up to 5 cm, depending on source and individual; the surgically defined anal canal averages approximately 4 cm [1, 5]. Reports of possible sex differences are inconsistent: while older teaching held that the anal canal is shorter in women, more recent functional measurements show comparable lengths in men and women [7].
- **Columns and crypts:** Both the number of anal columns and the number of anal crypts (four to twelve) vary between individuals without functional consequence [12].
- **Distribution of anal cushions:** The classic 3-7-11 o'clock pattern of the anal cushions represents an idealised description rather than a fixed rule. In one clinical series of patients with external haemorrhoids, cushion-

related findings were distributed as right posterior 34.1%, right anterior 28.2%, left lateral 17.1%, and left posterior 7.6%, with more than one quadrant affected in 72.5% of cases – indicating that the textbook three-cushion pattern is only one of several recognised distributions. The right posterior (7 o'clock) position was the single most frequently affected site [19].

- **Perianal fold pattern:** The expression and regularity of the radial skin folding show visible individual variation, influenced among other factors by skin elasticity, body composition, childbirth, and age. A single case report has additionally proposed a possible association between hypermobility-type Ehlers-Danlos syndrome – a heritable connective tissue disorder – and haemorrhoidal disease, raising the hypothesis that connective tissue quality more broadly may influence the supporting structures of the anal cushions and perianal skin; as case-level evidence, this association has not been confirmed in controlled studies [23].

For both clinical and general health-related interpretation, it is important that this variability alone carries no disease significance. A 'healthy' anus therefore shows a certain range of normal individual expression within an overall conserved anatomical basic plan.

3.7. Clinical Relevance

The anatomy described here has considerable clinical significance beyond purely descriptive interest. Clock-face nomenclature (12 o'clock = ventral in the lithotomy position) serves as an international standard for documenting lesion location, for example for fissures, which occur predominantly in the posterior midline (6 o'clock), or for fistula openings [21].

The modern understanding of the anal cushions as a physiological, continence-relevant structure has changed the treatment of haemorrhoidal disease: procedures such as rubber band ligation, sclerotherapy, or Doppler-guided transanal haemorrhoidal dearterialisation (THD) aim to reposition the cushions to their original anatomical location or to reduce their blood supply, rather than removing them radically – a direct consequence of understanding their physiological function [18].

The dentate line, as the boundary between different lymphatic drainage pathways – above it to the internal iliac nodes, below it to the superficial inguinal nodes – is also a central factor in diagnosis, staging, and treatment planning for anal canal and low rectal tumours, as well as for decisions regarding sphincter-preserving surgical procedures [1].

Finally, understanding of the anorectal angle and of puborectalis function is an essential basis for continence-preserving pelvic floor surgery and for the conservative management of continence and evacuation disorders, for example in the context of pelvic floor physiotherapy [13, 8].

Abbreviations

- IAS: Internal Anal Sphincter;
- EAS: External Anal Sphincter.

4. Conclusion

The form of the anus is not a static, simple detail of the body surface but the result of a complex interplay of an embryologically two-part tissue architecture, a three-layered muscular and sling system, specialised vascular cushions, and an actively maintained, radially folded skin surface. Each of these structures simultaneously fulfils a form-giving and a functional role: together they determine external and internal appearance while contributing to continence, defence, and the sensory discriminative capacity of the organ.

The anatomical literature describes the basic plan as largely conserved, while finer structural features – length, number of columns and crypts, distribution of the anal cushions, and expression of the perianal fold pattern – show a normal range of individual variation. Distinguishing between this conserved basic plan and normal formal variability is of fundamental importance both for clinical practice and for a general, matter-of-fact understanding of a body region that remains frequently stigmatised.

Compliance with ethical standards

Disclosure of conflict of interest

The author declares no conflict of interest.

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