CHAPTER 1

Anatomy of the Interior of the Anal Canal

The anal canal is the terminal part of the digestive tract between the rectum and the anus. Anteriorly the anal canal is separated from the vagina and the urethra by the perineal body. Posteriorly, it is separated from the coccyx by the anococcygeal ligament. Understanding the anatomy and function of the anal canal is essential in diagnosing and treating anorectal diseases.

ANAL CANAL

The anal canal runs anteroposteriorly and is enclosed by a strong muscular tube. It is entirely extraperitoneal (Fig. 1.1).

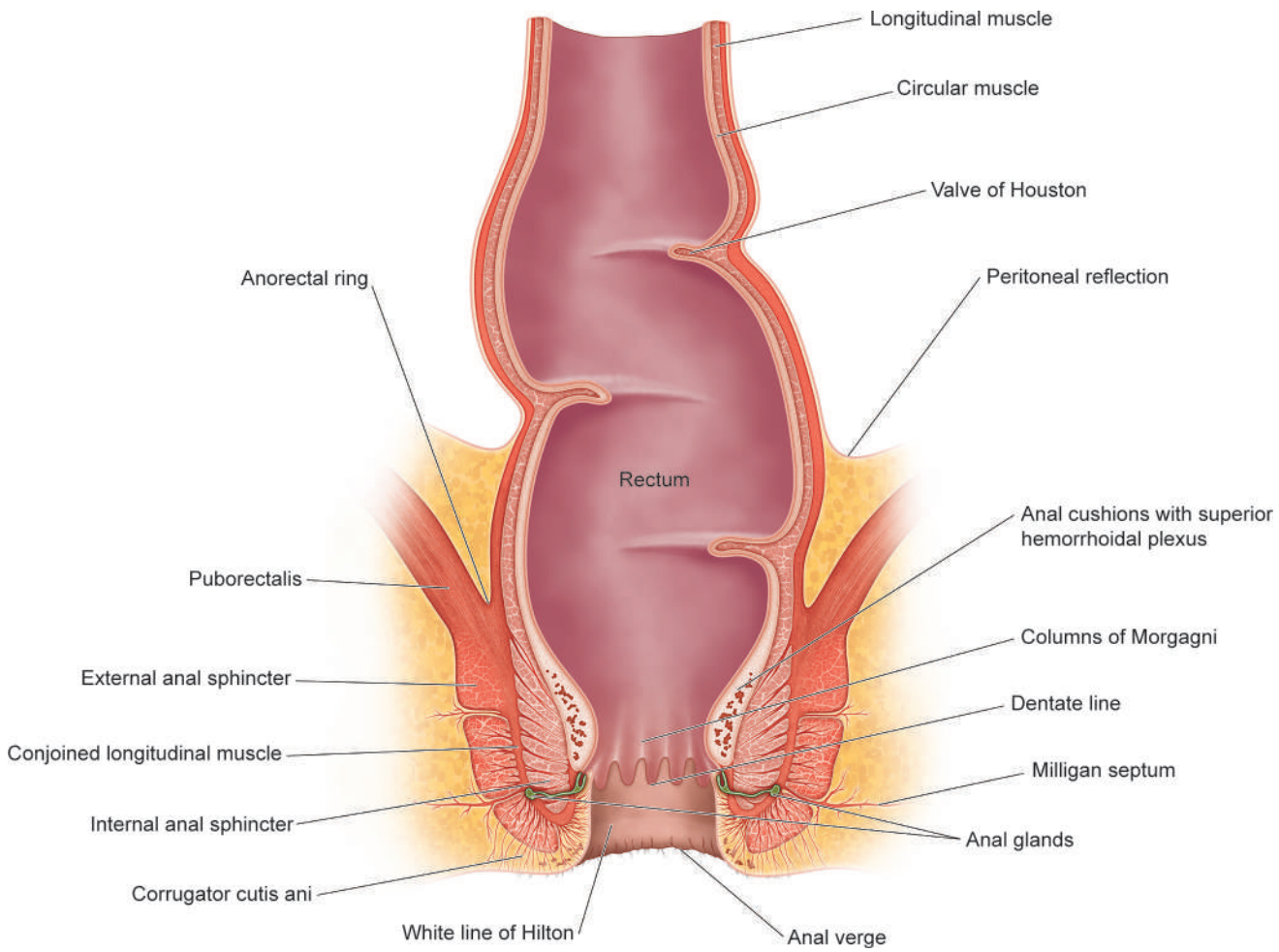


Fig. 1.1: Anal canal

The anal canal is described in two ways:

- **Anatomical anal canal**
  - 1.5–2.0 cm long
  - Extends from the anal verge to the dentate line
- **Surgical anal canal**
  - Measures about 4.0 cm in females and 4.4 cm in males.
  - Extends from the anal verge to the anorectal ring (Fig. 1.2A and B).

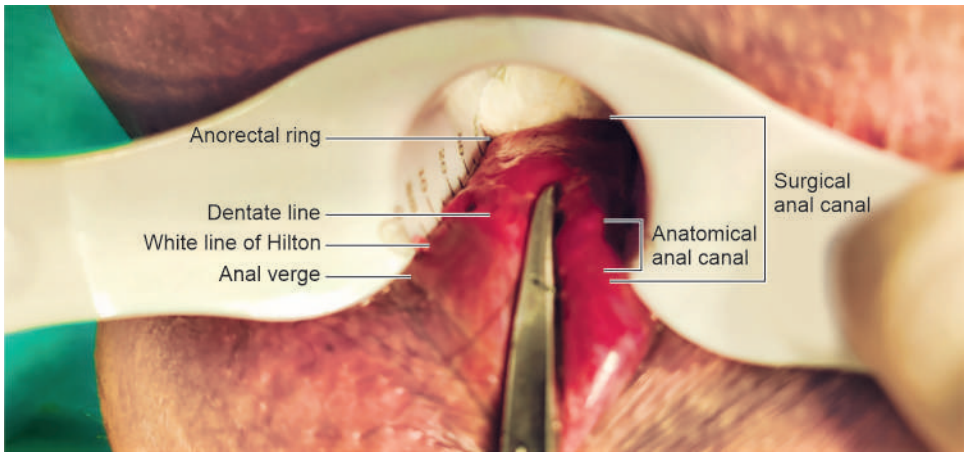


Fig. 1.2A: Proctoscopy view of the anal canal showing the surgical and anatomical anal canal. The artery forceps indicate the upper part of the anal canal

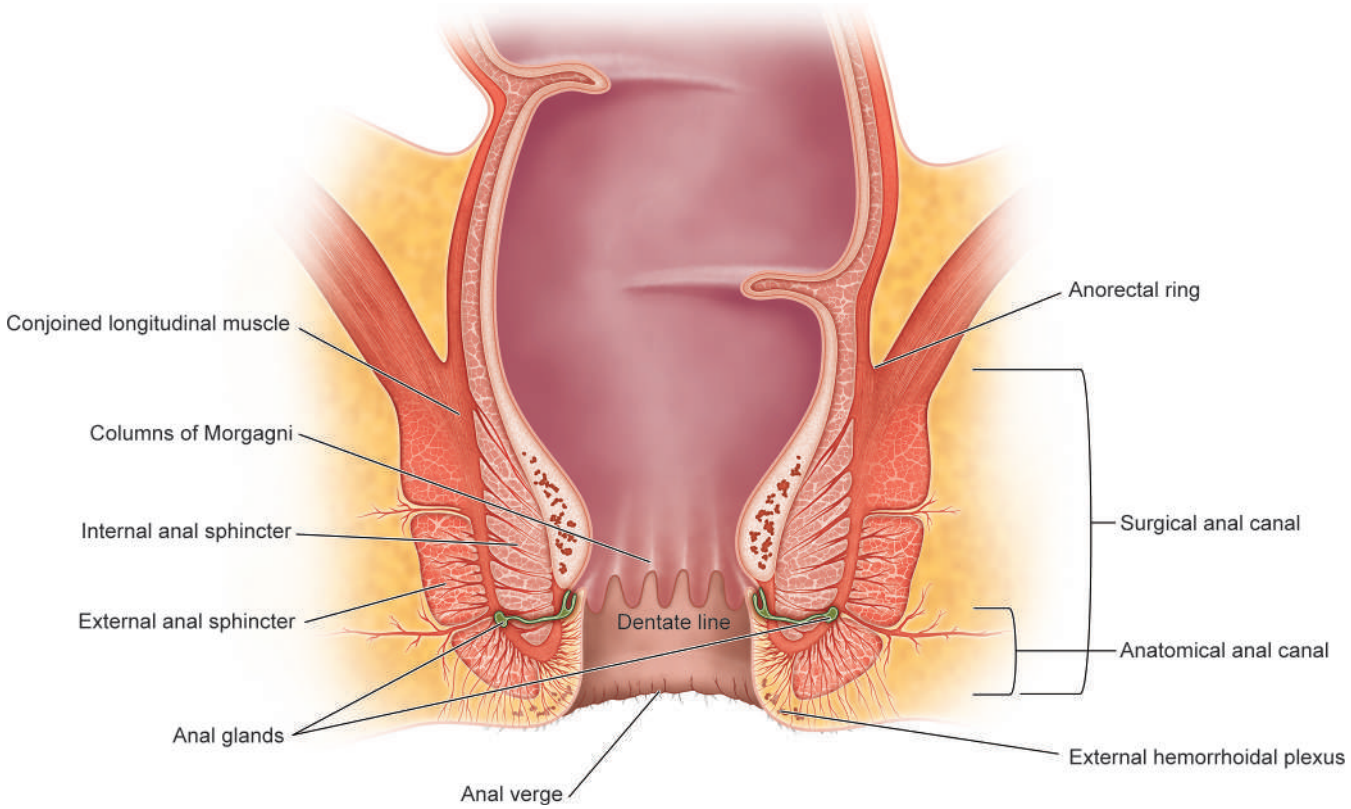


Fig. 1.2B: Diagrammatic representation of anatomical and surgical anal canal

INTERIOR OF ANAL CANAL

It is divided into three zones (Fig. 1.3A and B).

1. Upper Zone

The upper zone lies between the anorectal ring and the dentate line and is lined by columnar epithelium. It is approximately 2.5 cm long and comprises of:

- Columns of Morgagni
- Anal valves
- Anal sinus/crypts
- Pectinate/dentate line
- Anal papillae
- Anal cushions

2. Middle Zone

The middle zone lies between the dentate line and the intersphincteric groove (white line of Hilton). This is also known as the intermediate zone or area of pectin. It is lined by anoderm and is about 15 mm long.

3. Lower Cutaneous Zone

The lower cutaneous zone lies between the white line of Hilton and the perianal skin. It is approximately 8 mm long.

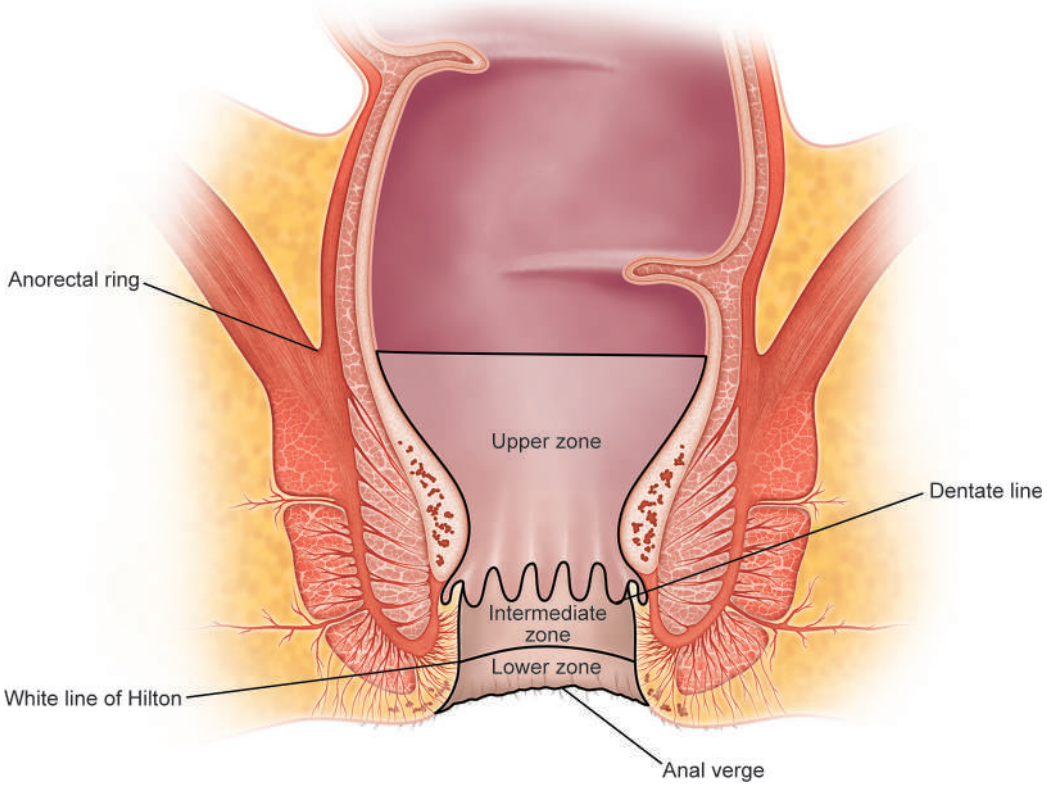


Fig. 1.3A: Three zones of the interior of the anal canal

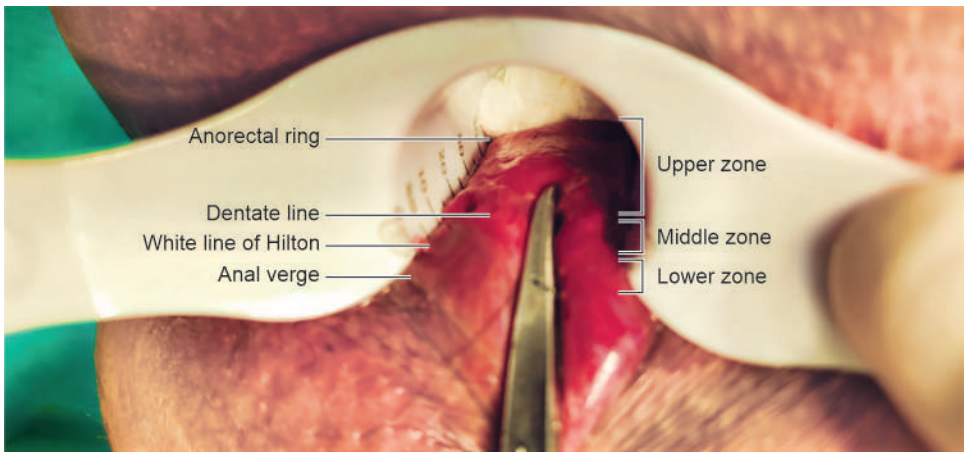


Fig. 1.3B: Proctoscopy view of the interior of the anal canal

UPPER ZONE–CONTENTS

Columns of Morgagni

- These are 12–16 vertical folds produced by the infoldings of the mucous membrane.
- These are separated by another furrow called anal sinuses.
- The mucosal membrane epithelium comprises cuboidal cells that transform into columnar cells in the rectal mucosa present above (Fig. 1.4A and B).

Surgical Significance

Below the columns of Morgagni, anal crypts are present where the ducts of anal glands open.

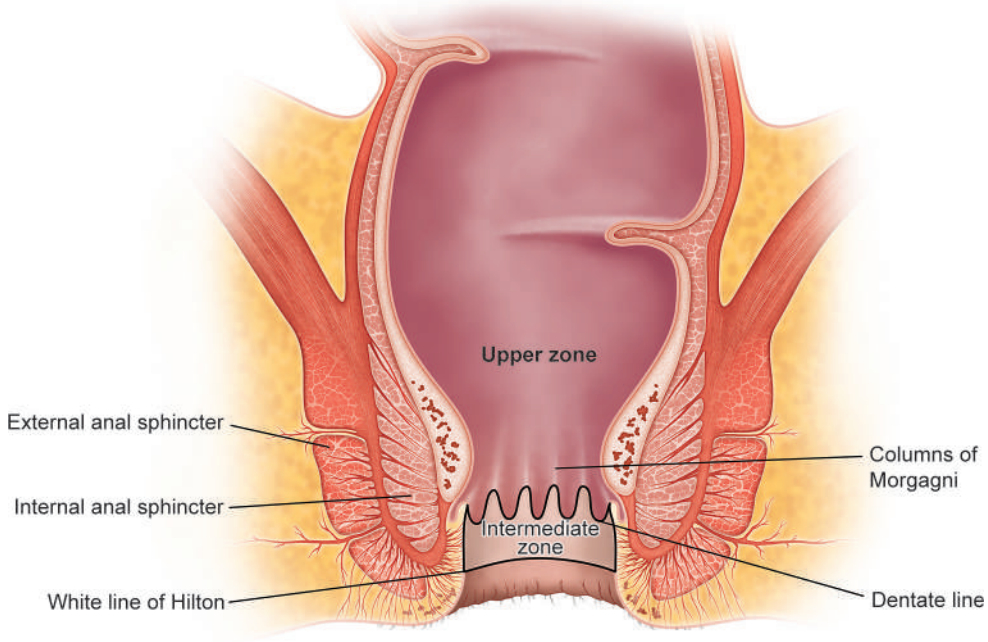


Fig. 1.4A: Diagrammatic representation of columns of Morgagni

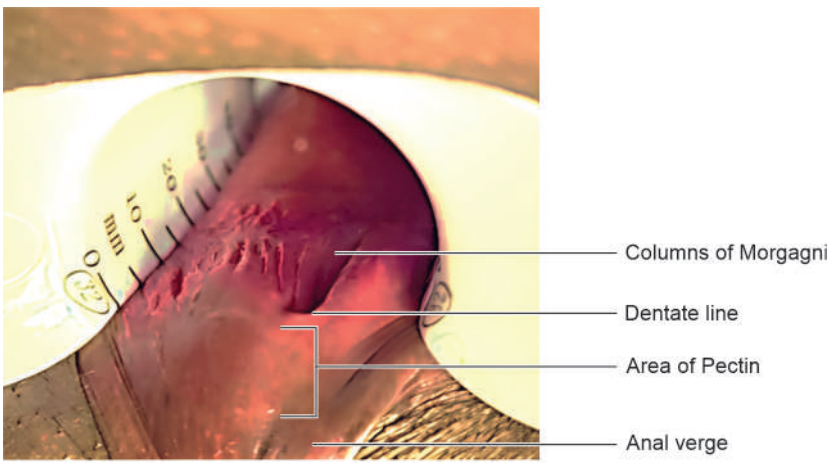


Fig. 1.4B: Proctoscopy view of columns of Morgagni

Anal Valves

- Anal valves are small transverse folds of the mucous membrane that join the lower ends of columns of Morgagni (Fig. 1.5). These valves are 2 cm cranial to the anus.
- The valves and sinuses are more prominent on the posterior wall of the anal canal (Fig. 1.5).

Surgical Significance

Chronic constipation can cause tearing of the anal valves up to the anus, leading to anal fissures.

Anal Sinuses/Crypts

- Anal crypts are small recesses between neighbouring anal columns and behind the anal valves. They vary in number, shape, and depth.
- Each anal crypt is attached to one or more anal glands (Fig. 1.6).

Surgical Significance

The ducts of the anal glands open at the crypts. Clinically, it is the site for the internal opening in anal fistulas.

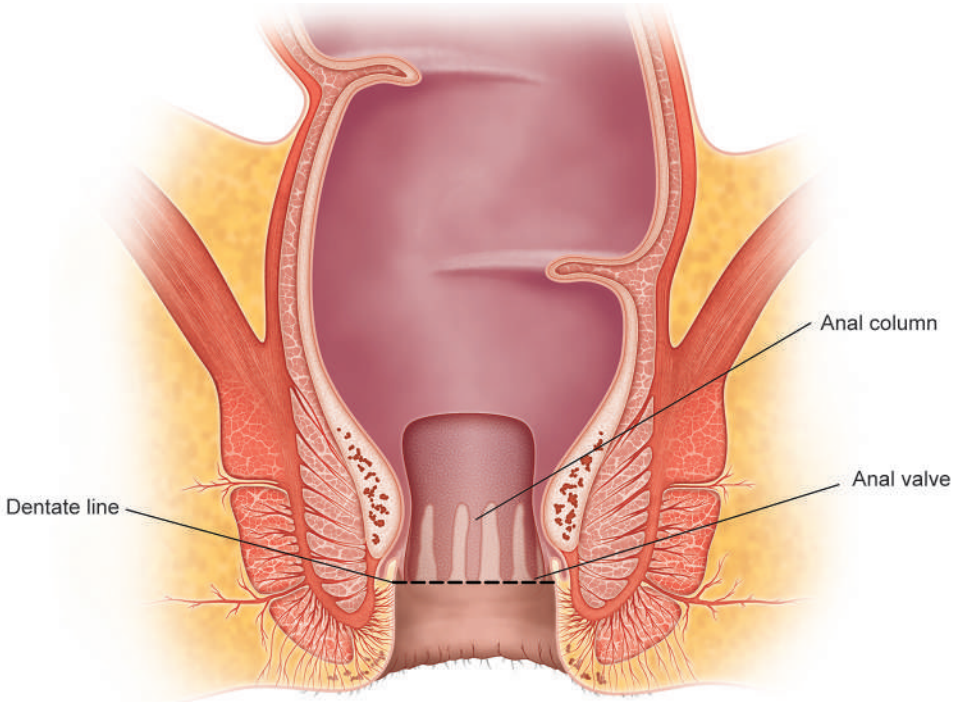


Fig. 1.5: Diagrammatic representation of the anal valve

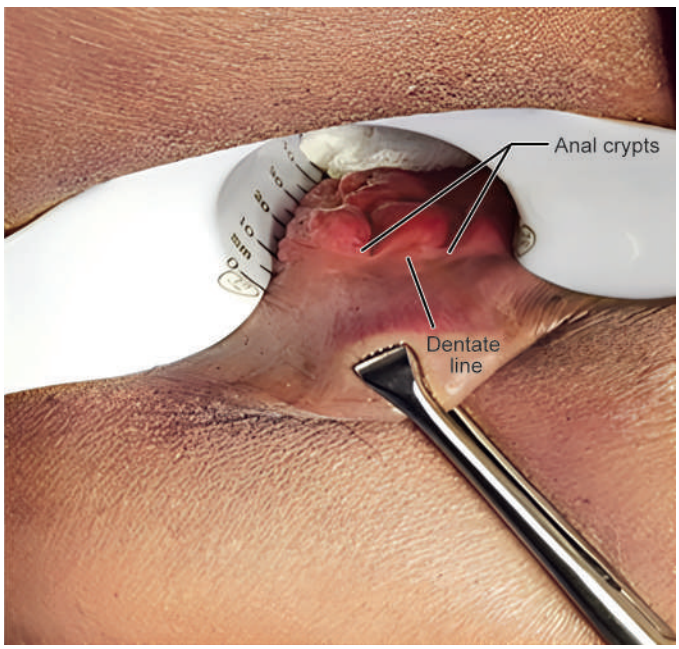


Fig. 1.6: Proctoscopy view of anal crypts

Anal Glands

- The anal glands are around 6–8 in number and are primarily located posteriorly.
- The ducts of the anal glands open at the anal valves at the dentate line (Fig. 1.7).

Surgical Significance

Obstruction of the anal glands leads to stasis with the formation of anal abscesses and fistulas.

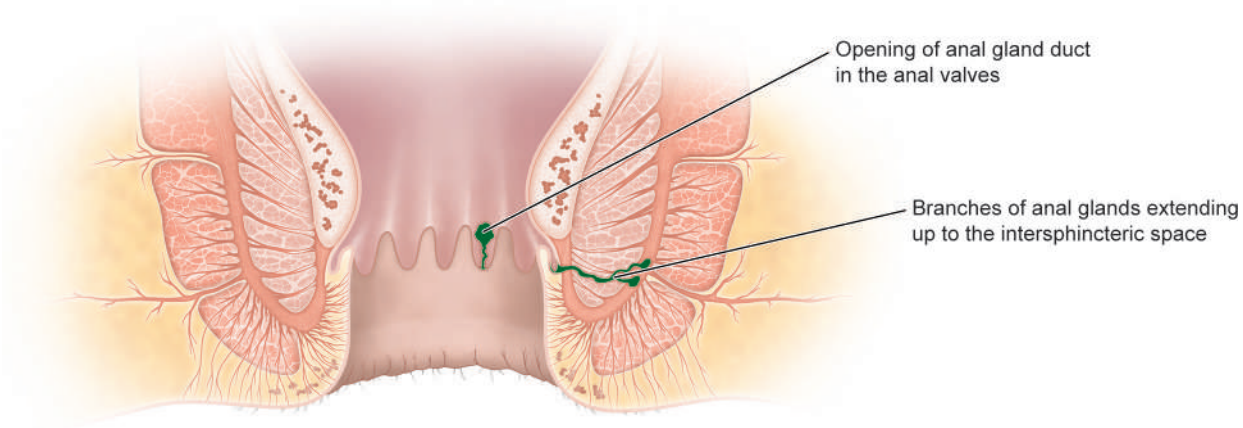


Fig. 1.7: Diagrammatic representation of anal glands

Dentate Line

- The anal valves form a saw-tooth-like transverse line called the pectinate or dentate line. It represents the junction of the proctodeum and the hindgut.
- The anoderm comprising of non-keratinized squamous epithelium is below the dentate line and extends up to the white line of Hilton. It is shiny, pink and devoid of glands and hair follicles.
- Anal papillae are present on the dentate line (Fig. 1.8A and B).

Surgical Significance

- The blood supply, lymphatic drainage and nerve supply above and below the dentate line are entirely different, which has a great surgical significance.
- As internal hemorrhoids are present above the dentate line, they are painless, while the external hemorrhoids are painful since they are present below the dentate line.
- In an anal fissure, a linear tear extending from the dentate line to the anal verge, causes severe pain during defecation.

Blood supply, lymphatic drainage and nerve supply above and below the dentate line (Table 1.1).

TABLE 1.1: BLOOD SUPPLY, LYMPHATIC DRAINAGE AND NERVE SUPPLY

	Below the dentate line	*Above the dentate line*
Arterial blood supply	Inferior rectal artery	Superior and middle rectal artery
Venous drainage	Inferior rectal vein (Systemic)	Superior rectal vein (Portal)
Lymphatic drainage	Superficial inguinal nodes	Internal iliac nodes
Nerve supply	Somatic (Pudendal nerve)	Autonomic

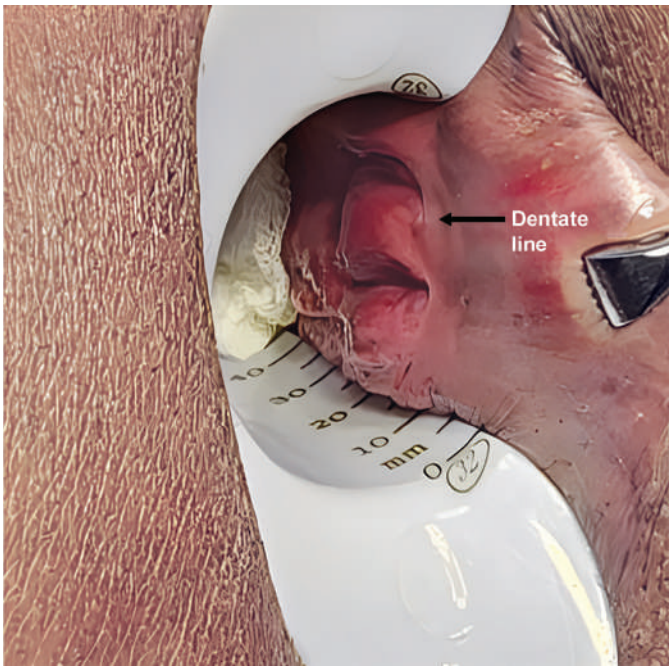


Fig. 1.8A: Proctoscopy view of the dentate line

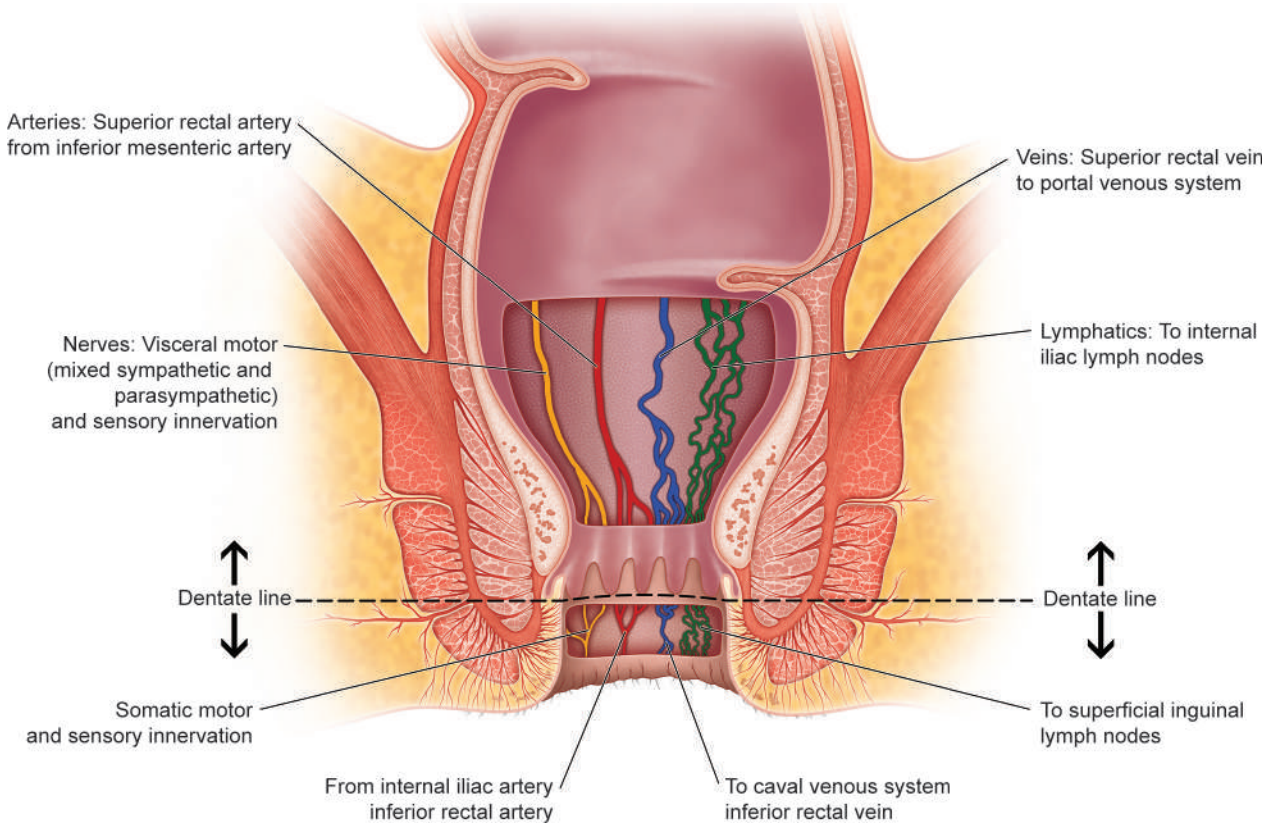


Fig. 1.8B: Diagrammatic representation showing the blood supply, venous and lymphatic drainage, and nerve supply above and below the dentate line

Anal Papillae

- They are remnants of the embryonic anal membrane. At the dentate line, these appear as tiny epithelial projections (Fig. 1.9).
- Constant irritation, damage, or infection can cause enlargement of the papillae. The condition is known as "Hypertrophic anal papillae."

Surgical Significance

Large hypertrophic anal papillae can cause difficulty in defecation. The patient has a peculiar history of "shutter-like effect" near the anal orifice at the time of defecation.

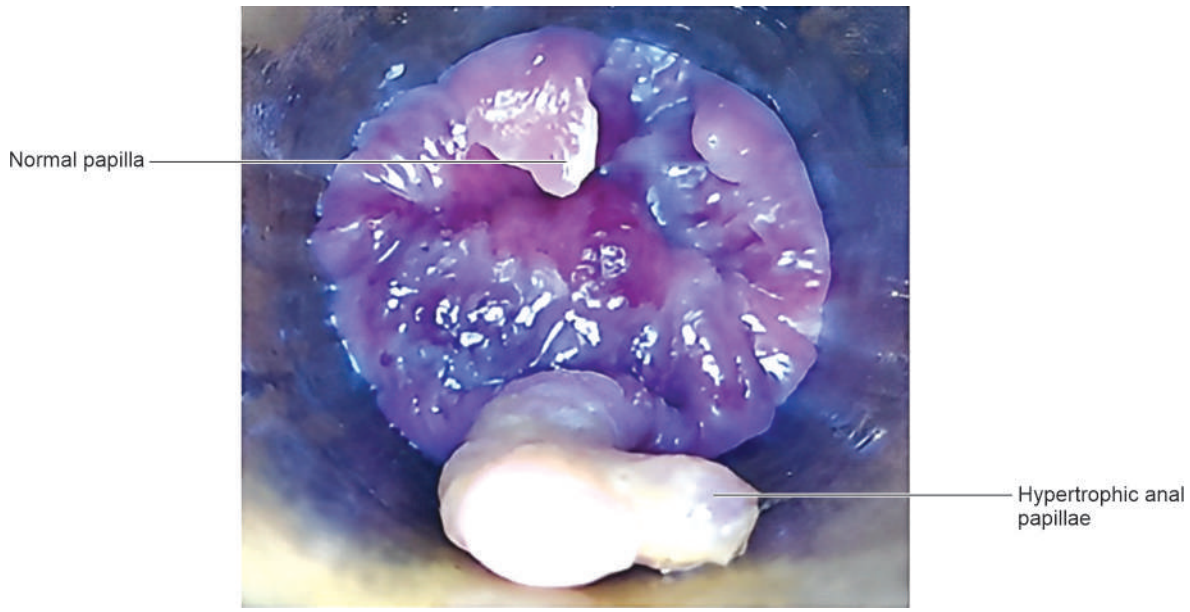


Fig. 1.9: Hypertrophic anal papillae

Anal Cushions

- The three significant cushions inside the anal canal are at the left anterior, right posterior and right anterior regions, also known as the 3, 7 and 11 o'clock positions.
- These cushions are deep purple, and hemispherical, representing the disruptions of the submucosa and extending towards the upper surgical canal. An accessory cushion is sometimes present posteriorly at 6 o'clock (Fig. 1.10A and B).

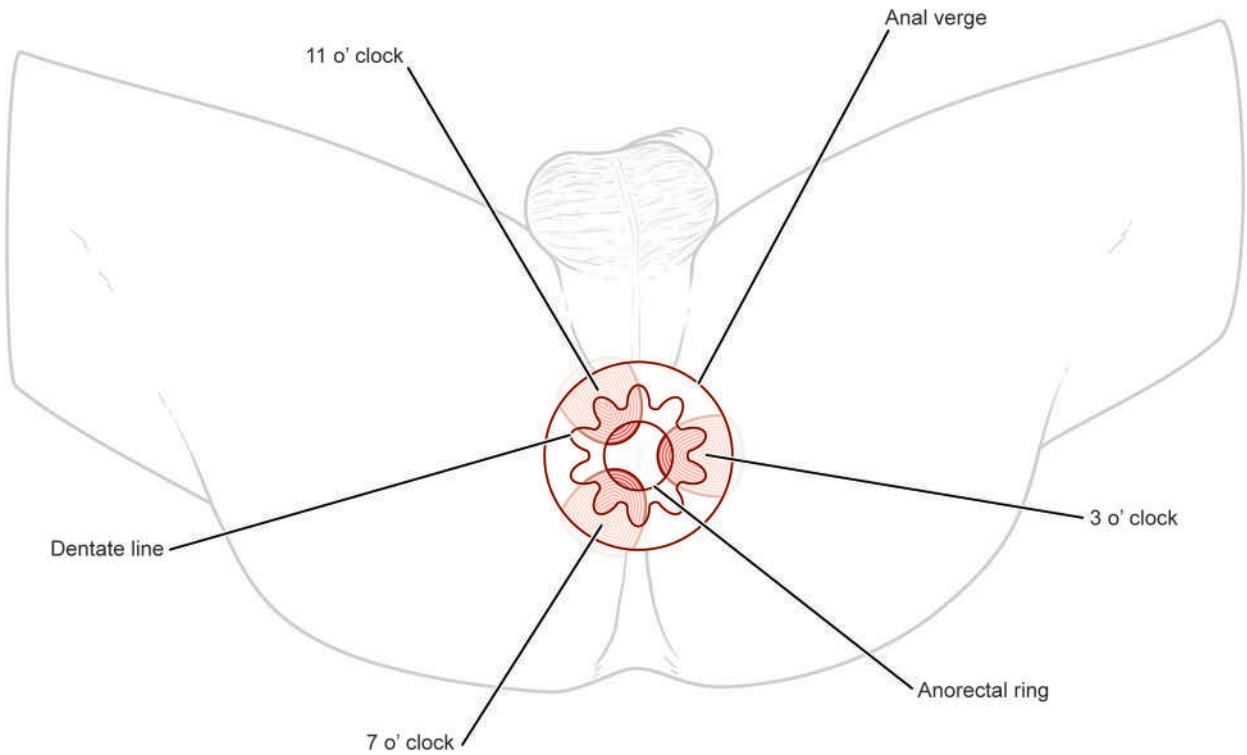


Fig. 1.10A: Diagrammatic representation of the position of anal cushions

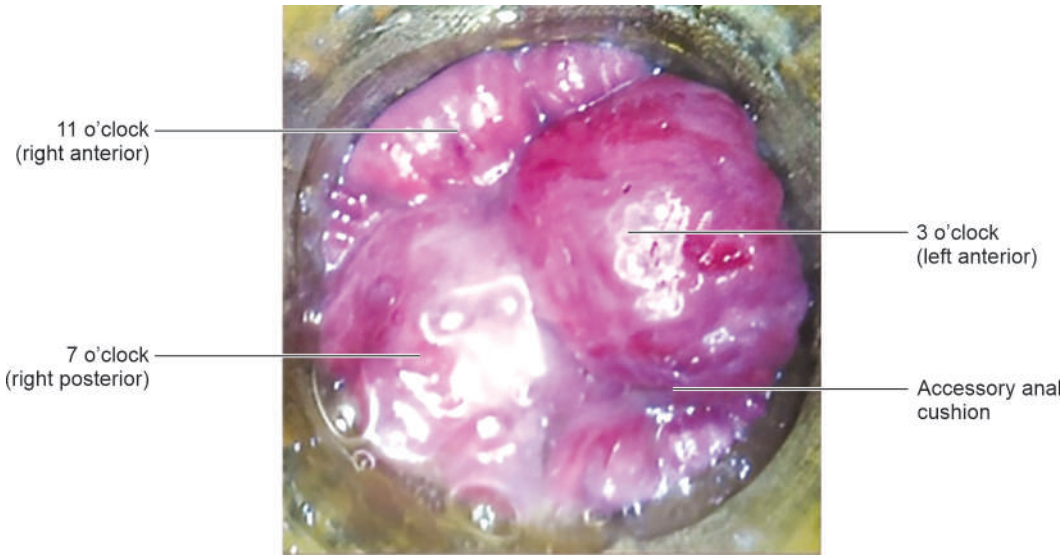


Fig. 1.10B: Proctoscopy view of the positions of primary and accessory anal cushions

Components of Anal Cushions

- *Nonvascular:* Comprises connective tissue and fibres of Treitz ligament. The weakening and disintegration of these fibres cause prolapse of the anal cushions.
- *Vascular:* Comprises the superior hemorrhoidal artery branches that form an arteriovenous network. These are the sinusoids which are lined by endothelium and form fenestrations. They form a spongy network called the corpus cavernosum recti (CCR), comparable to the penile erectile tissue. A mucosal suspensory ligament is present between the sinusoids (Fig. 1.11).

Surgical Significance

- Anal cushions facilitate anal closure to maintain continence. They maintain 15–20% of resting anal pressure.
- Inflammation of the anal cushions leads to the formation of hemorrhoids.

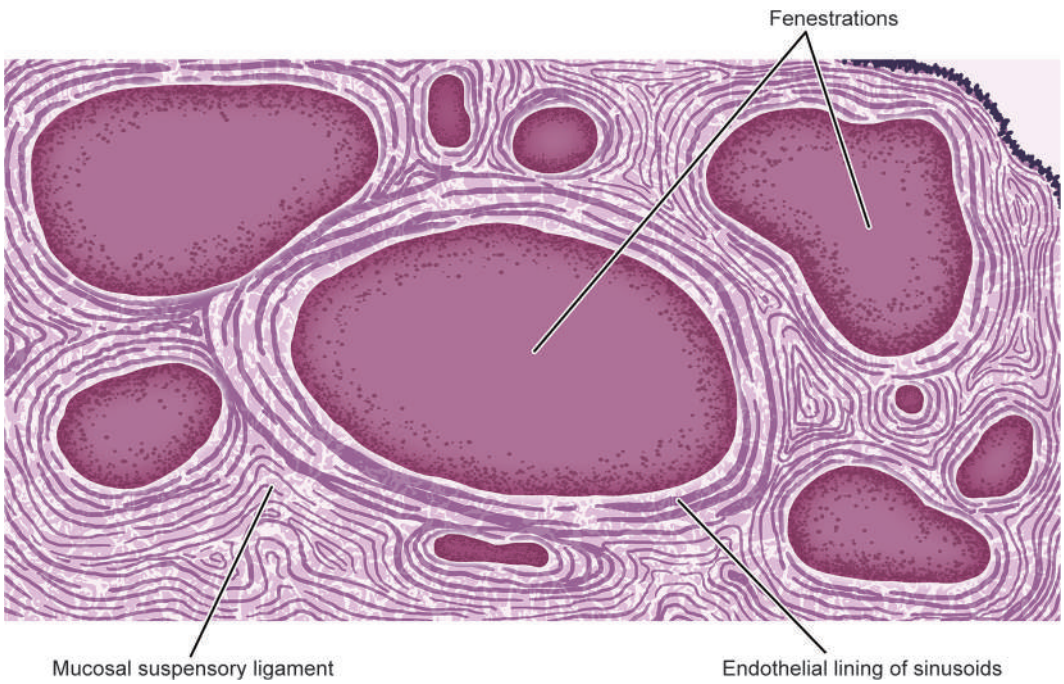


Fig. 1.11: Histological appearance of sinusoids

Ligament of Treitz

- The fibres of the ligament of Treitz originate from the conjoined longitudinal muscle (CLM), pierce the internal sphincter, and play a vital role in anchoring the anal cushions (Fig. 1.12).
- The Treitz muscle has two parts: The anal submucosal muscle, which fixes the "cushions to the internal anal sphincter", and the mucosal suspensory ligament that "fixes sinusoids to the CLM".

Surgical Significance

- The disintegration of submucosal fibres leads to the sliding of anal cushions. The hemorrhoids are classified based on the degree of descent of anal cushions (sliding anal cushion theory by Thomson).
- The weakening of the mucosal fibres leads to venous stasis, an important etiological factor for the formation of hemorrhoids (Fig. 1.12).

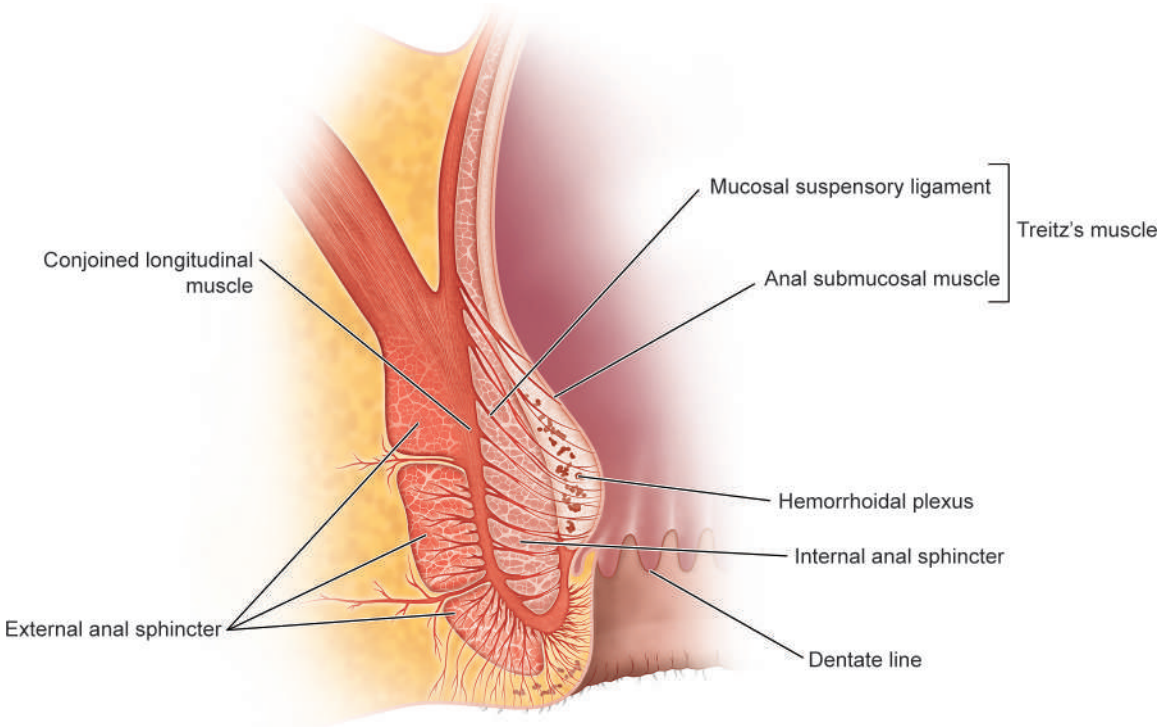


Fig. 1.12: Ligament of Treitz

Anal Transition Zone

- The anal transitional zone (ATZ) is a 0.5–1.0 cm long mucosal strip above the dentate line (Fig. 1.13). The epithelium changes to a single layer of columnar cells cephalad to this region, resulting in the distinctive pink colour of the rectal mucosa.
- The mucosa in the anal transitional zone can analyze the rectal contents and distinguish between gas, liquid, and solid feces.

Surgical Significance

The excision of the anal transitional zone can lead to an urgency to defecate.

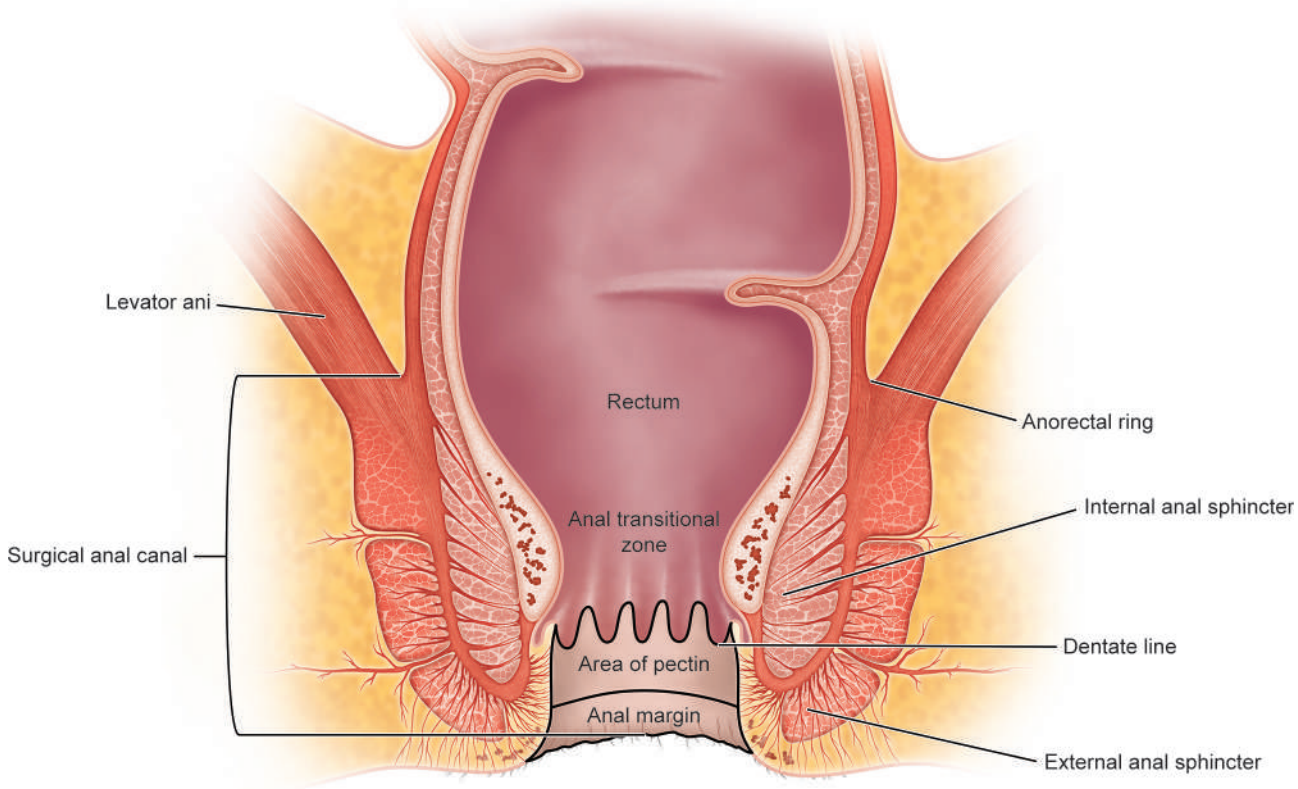


Fig. 1.13: Anal transitional zone (ATZ)

Middle or Intermediate Zone or Area of Pectin

- The intermediate zone is 1–1.5 cm long and is separated from the lower zone by the "white line of Hilton". This area is known as the "area of pectin" and is lined by stratified squamous non-keratinized epithelium (Fig. 1.14A and B).

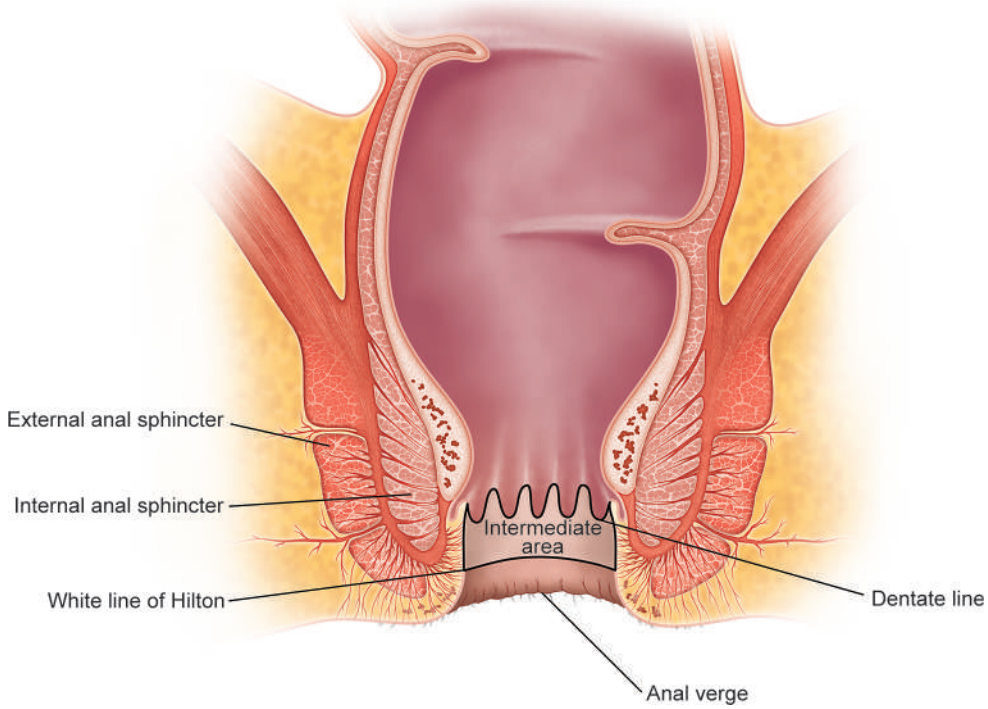


Fig. 1.14A: Intermediate zone and white line of Hilton

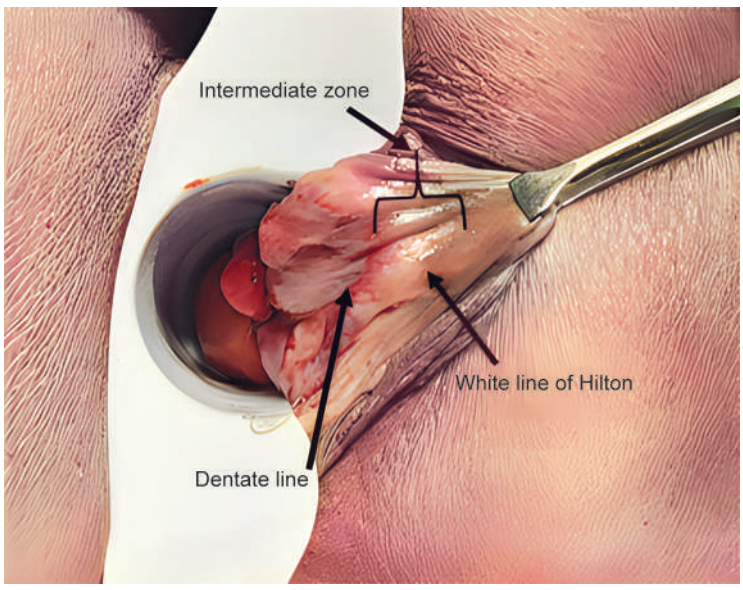


Fig. 1.14B: Proctoscopy view showing intermediate zone, dentate line and white line of Hilton

Lower Cutaneous Zone

- The lower cutaneous zone is approximately 8 mm long and extends between the white line of Hilton and the anal verge.
- It is lined by stratified squamous keratinized epithelium and has sebaceous glands, hair follicles, and sweat glands (Fig. 1.15).
- It continues with the perianal skin inferiorly.

Surgical Significance

- The internal anal sphincter in the intermediate zone is spastic. Anal fissures extend up to the dentate line for this reason.
- The "white line of Hilton" corresponds to the intersphincteric groove.
- The rupture of small tributaries of the inferior rectal vein during straining and coughing can cause clot formation in the subcutaneous tissue, a condition known as perianal hematoma.
- The lower cutaneous zone is a protective barrier between the anal canal and the external environment.

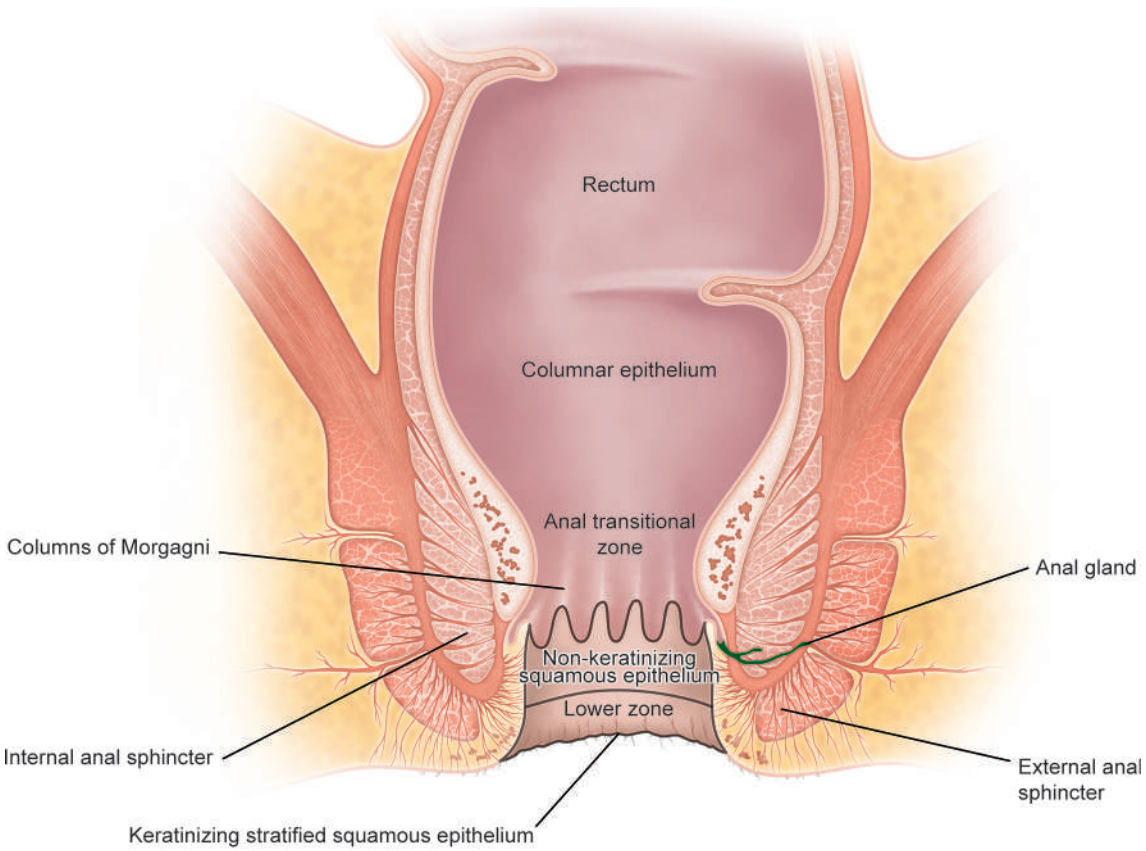


Fig. 1.15: Lower cutaneous zone

A Word about Mucocutaneous Junction

According to John Hilton, the white line of Hilton represents the mucocutaneous junction. The anoderm covering the intermediate zone is not true skin as it is shiny and pink and lacks hair follicles and sweat glands. Many authors believe the dentate line should be considered as the mucocutaneous junction (Fig. 1.16A and B).

Surgical Significance

- According to some authors, the white line of Hilton represents mucocutaneous junction. Others consider the dentate line as mucocutaneous junction.
- The junction is the landmark for fibre insertion during laser hemorrhoidoplasty.

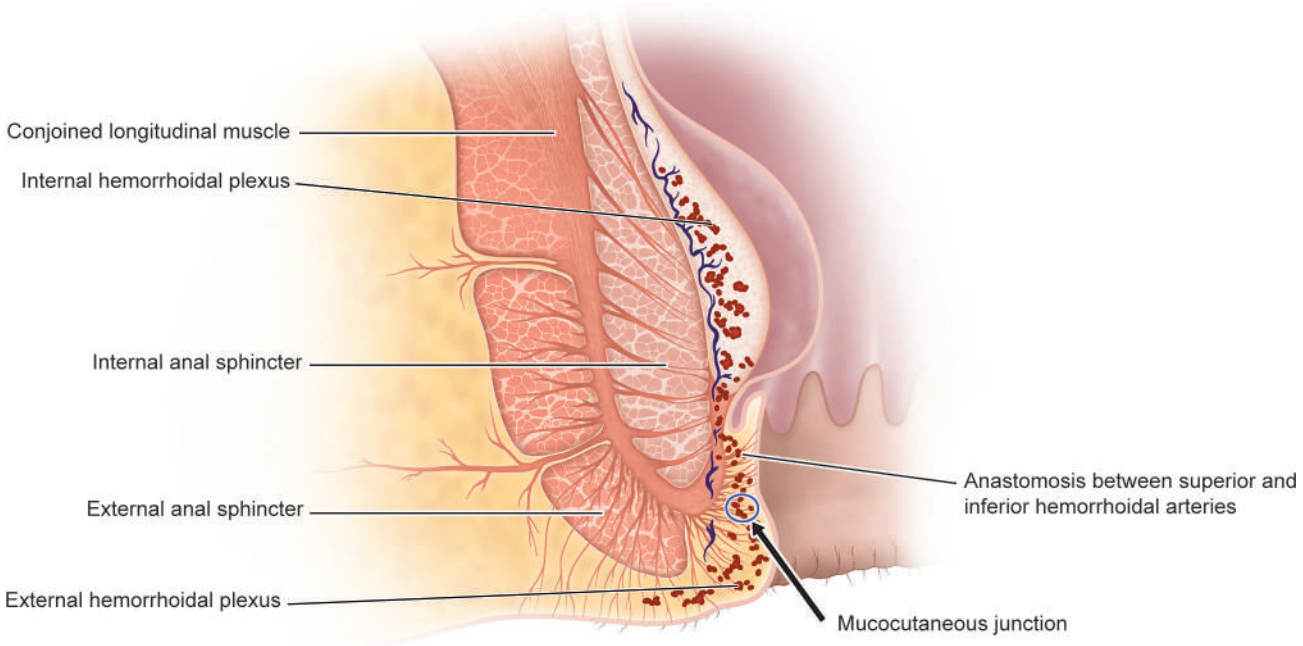


Fig. 1.16A: Mucocutaneous junction

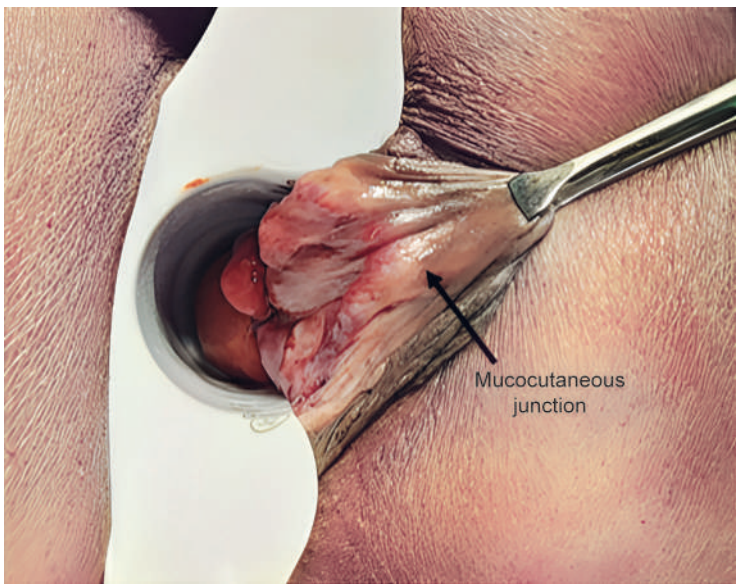


Fig. 1.16B: Proctoscopy view of mucocutaneous junction

Blood Supply of the Anal Canal

Arterial Supply

The main arteries that supply the anal canal are

- The superior hemorrhoidal artery (SHA). It is an extension of the inferior mesenteric artery.
- The middle hemorrhoidal artery (MHA). It originates from the anterior division of the internal iliac artery, inferior vesical artery, or both and is present only in 40–60% of the cases.
- The inferior hemorrhoidal artery (IHA). It originates from the internal pudendal artery, a branch of the internal iliac artery's anterior division (Figs 1.17 and 1.18).

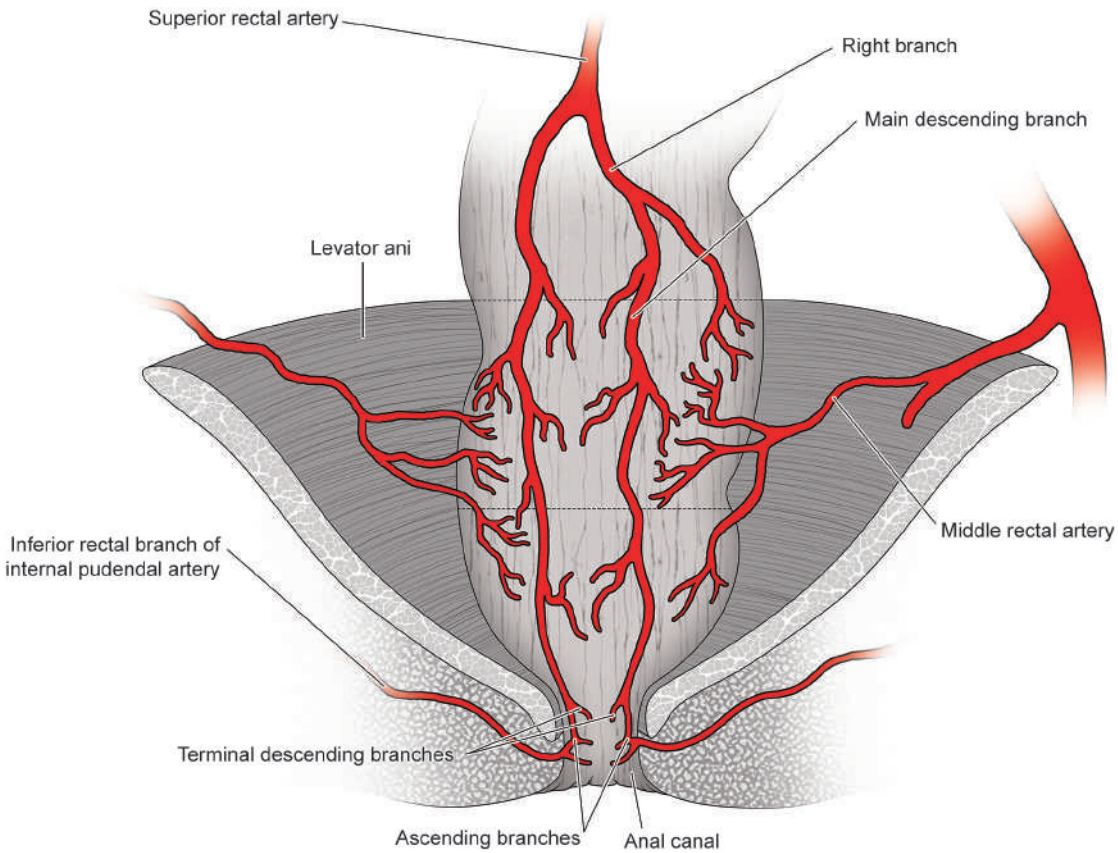


Fig. 1.17: Blood supply of the anal canal

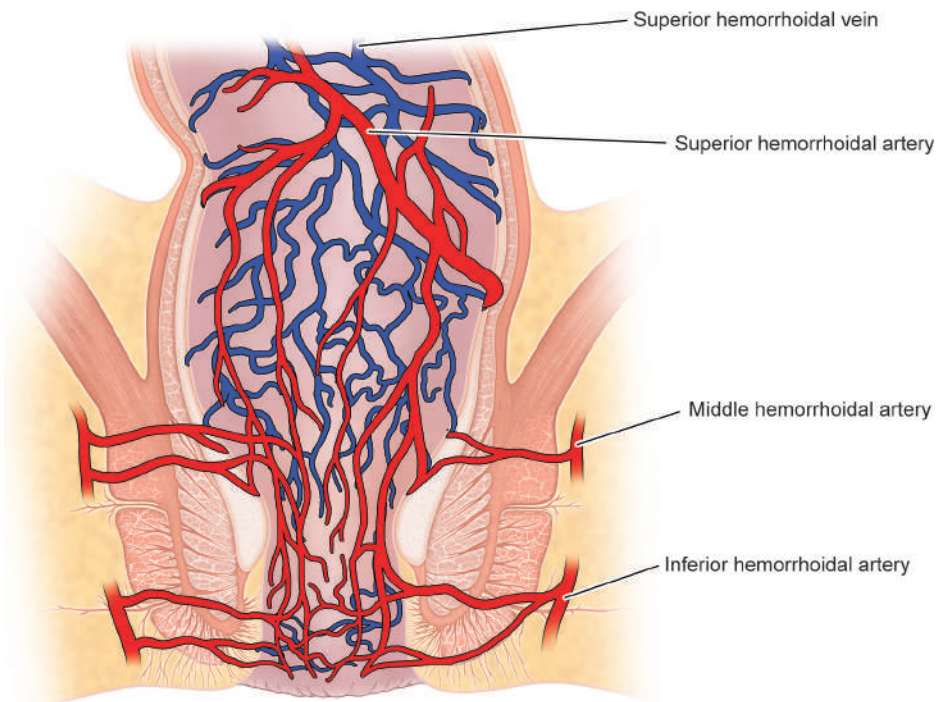


Fig. 1.18: Arterial blood supply of anal canal

Venous Supply

The veins correspond to the arterial supply. The superior hemorrhoidal vein continues as the inferior mesenteric vein to join the splenic vein. The internal iliac veins receive drainage from the inferior and middle hemorrhoidal veins. A portocaval anastomosis is formed through communication between the hemorrhoidal plexuses. However, hemorrhoidal engorgement is an uncommon occurrence. Instead, true rectal varices may develop in portal hypertension (Fig. 1.19).

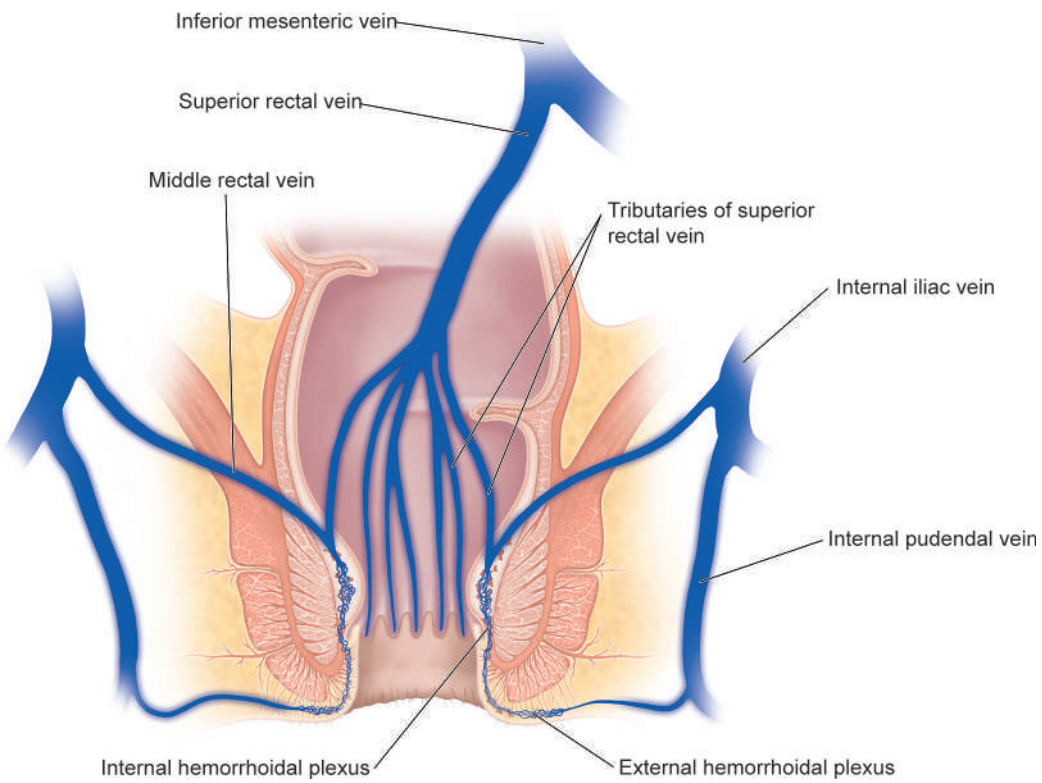


Fig. 1.19: Venous supply of anal canal

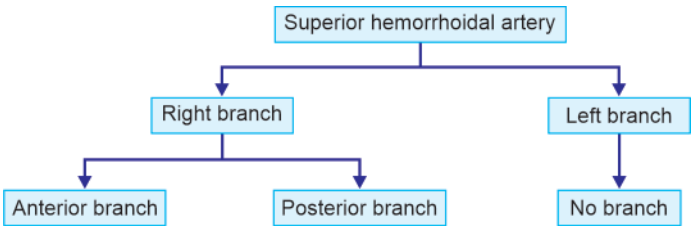
Branching Pattern of Superior and Inferior Hemorrhoidal Arteries

Superior Hemorrhoidal Artery (SHA) Branching Pattern

SHA divides into left and right branches opposite the third sacral vertebra. The right branch divides into anterior and posterior branches, which further gives three to four branches 10–12 cm above the dentate line. The left branch does not divide further (Flowchart 1.1). The superior hemorrhoidal artery branches cross the rectal wall's muscular layer above the levator ani, reach the submucosa and form the corpus cavernosum recti (CCR). A few branches of the SHA follow the extramural, transmural, and intramural course and participate in forming the CCR. The superior hemorrhoidal artery bifurcates in 82% of cases and trifurcates in 12% of cases (Figs 1.19 to 1.21).

The superior hemorrhoidal artery is the sole contributor to the corpus cavernosum recti formation (Fig. 1.21).

Flowchart 1.1: The chart representing the branching pattern of superior hemorrhoidal artery



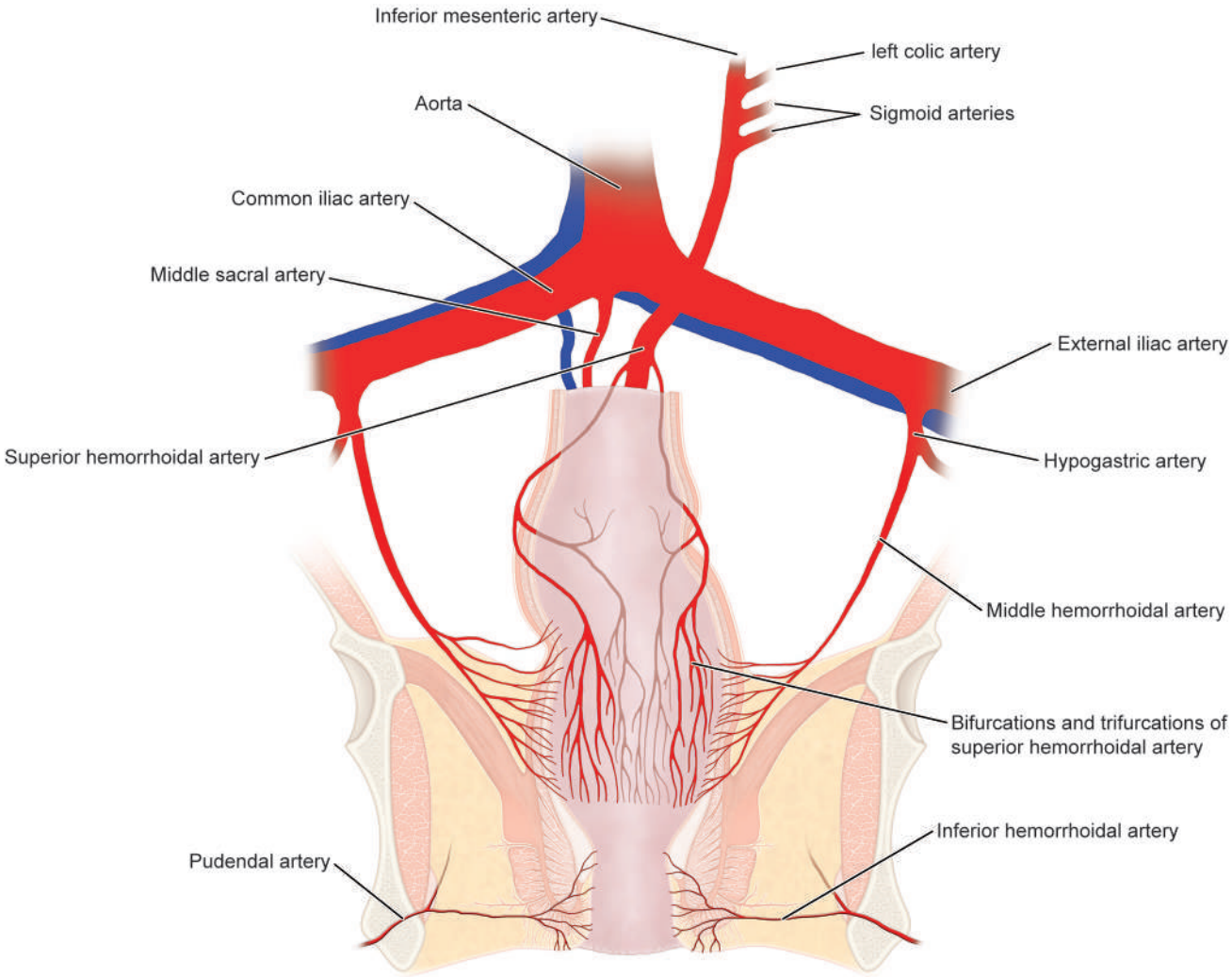


Fig. 1.20: Superior hemorrhoidal artery bifurcations and trifurcations

Surgical Significance

- The superior hemorrhoidal artery forms the corpus cavernosum recti, and its hyperplasia leads to the formation of hemorrhoids (Figs 1.21 and 1.22).
- The posterolateral branches arising from SHA are extremely high at the level of the anorectal ring. Thus, it is impossible to ligate them while performing hemorrhoidal artery ligation (Fig. 1.22).
- Two surgical procedures effectively take care of CCR in hemorrhoidal disease; one is hemorrhoidal artery ligation with laser hemorrhoidoplasty, and the other is excisional hemorrhoidectomy.

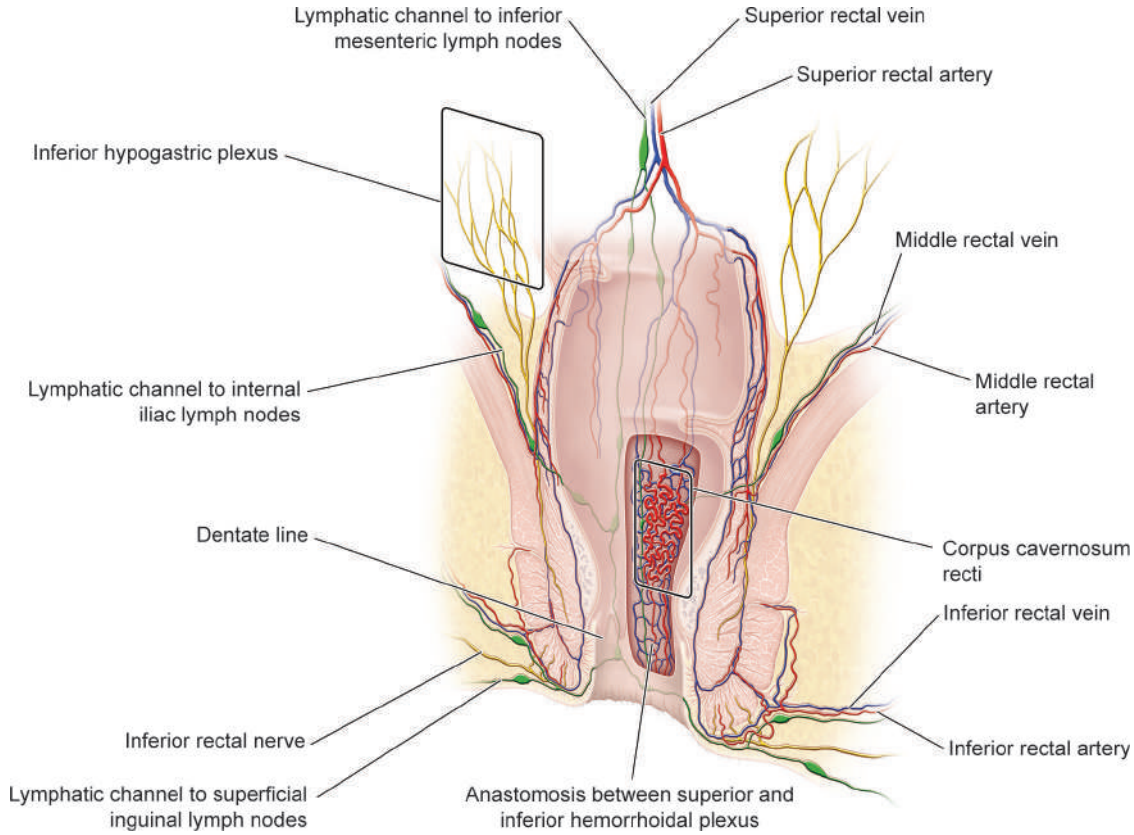


Fig. 1.21: Superior hemorrhoidal artery and formation of corpus cavenosum recti

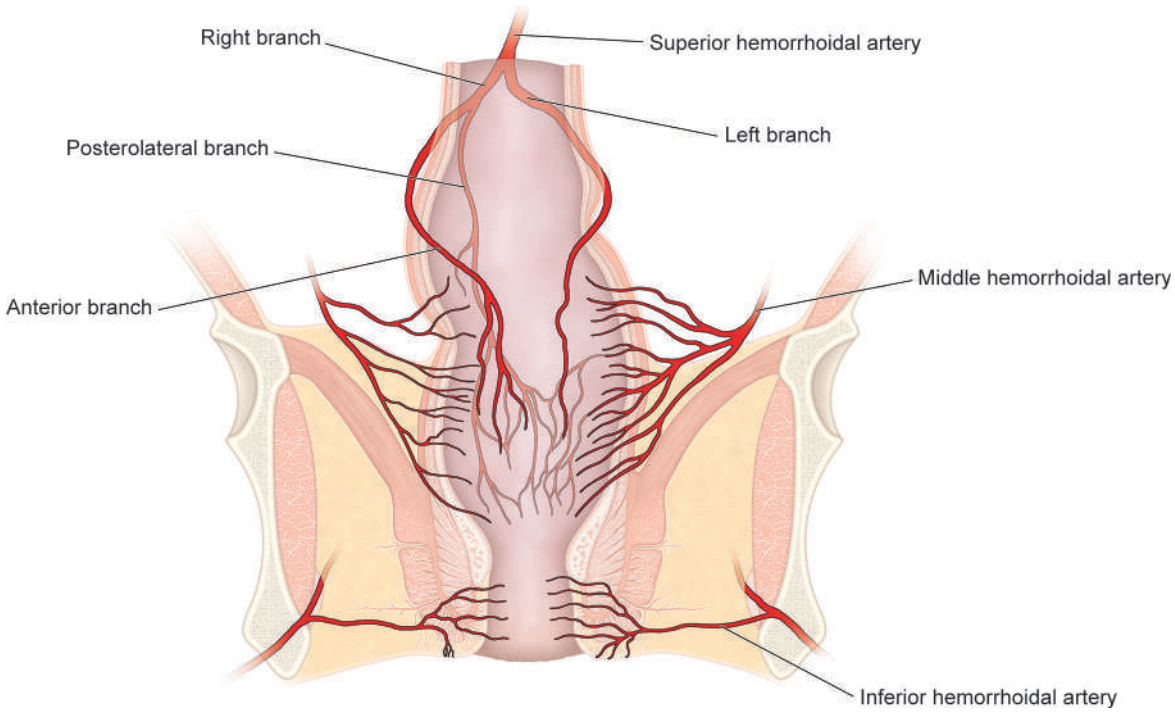


Fig. 1.22: Posterolateral branches of the superior hemorrhoidal artery

Inferior Hemorrhoidal Artery (IHA) Branching Pattern

The IHA has three main branches.

First branch: Directed posteriorly and upwards and supplies to the levator ani muscles, the adjacent portion of obturator internus and gluteus maximus.

Second branch: Directed towards the posterior aspect of anal canal musculature. It gives branches supplying the anococcygeal ligament and the posterior aspect of the anal canal musculature.

Third branch: This is the largest branch. It is directed toward the mediolateral aspect of the anal sphincters. It finally reaches the subepithelial musculature and anastomose with the superior and middle hemorrhoidal artery branches.

Surgical Significance

The inferior hemorrhoidal artery and inferior hemorrhoidal vein form an inferior hemorrhoidal plexus in the perianal space, which may lead to external hemorrhoids.

Anatomical Variations In the Presentation of the Superior Hemorrhoidal Artery

A surgeon must know the anatomical variations of the superior hemorrhoidal artery. Lack of understanding can lead to the recurrence of hemorrhoids in the surgical procedures which are based on the principle of dearterialization.

- The significance of the superior hemorrhoidal artery lies in its crucial role in maintaining the blood supply to the rectum and anal canal and its relevance in the context of hemorrhoids and related surgical procedures.
- Procedures like Doppler-guided hemorrhoidal artery ligations and transanal suture hemorrhoidopexy are based on the principle of dearterialization, which subsequently leads to fibrosis. Although the branches of SHA present in the submucosa can be ligated, the posterolateral branches of SHA are too high and deep. Hence, interruption of complete blood circulation to the hemorrhoidal mass is impossible.
- The extra rectal course of these arteries makes it difficult for the surgeon to ligate them during hemorrhoidal artery ligation procedures (Fig. 1.23A to E).

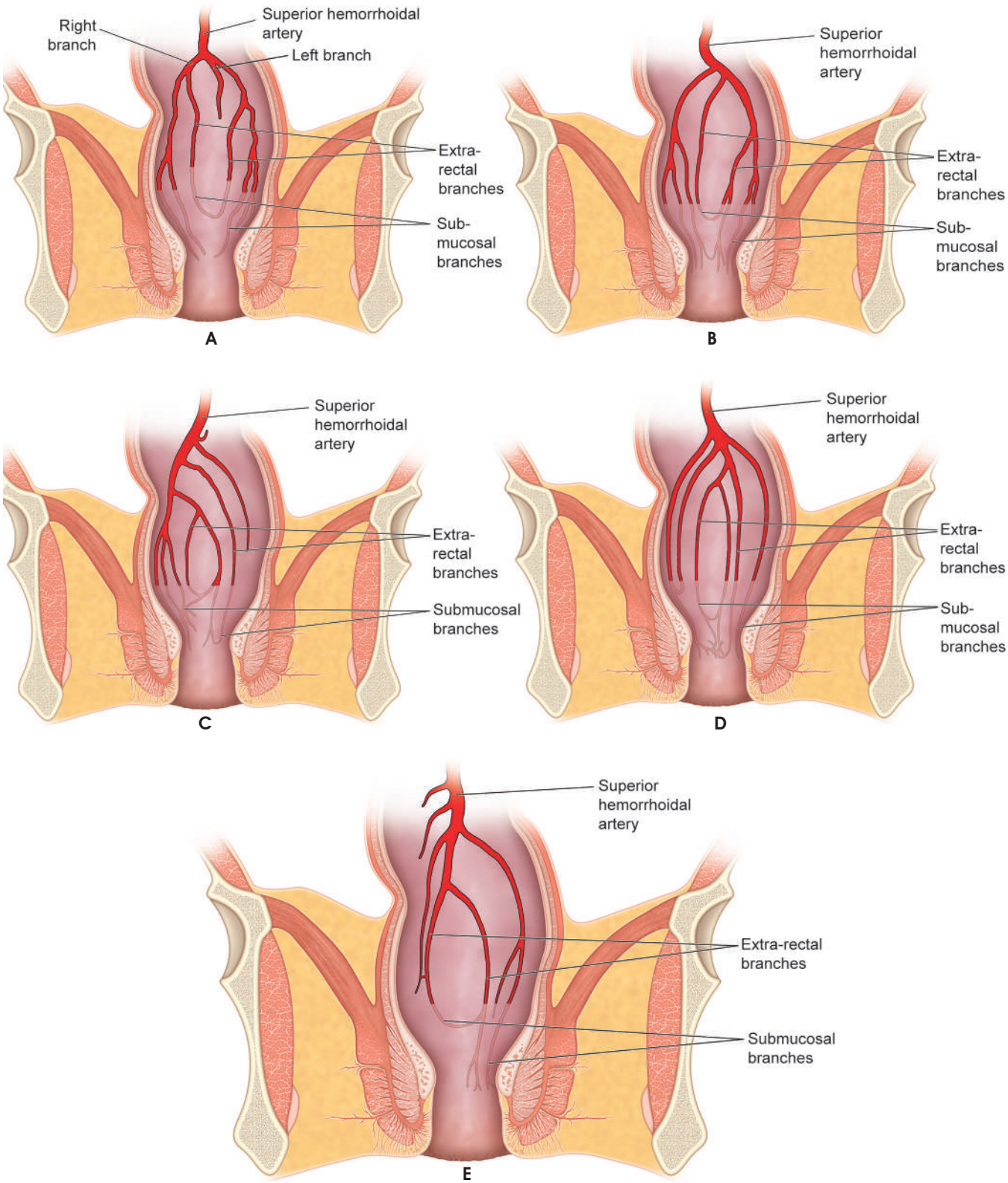


Fig. 1.23A to E: Different patterns of the superior hemorrhoidal artery and its course. *Thomson H. Piles their nature and their management*

Hemorrhoidal Plexus

Superior Hemorrhoidal Plexus

- The superior hemorrhoidal plexus is formed by the anastomosis of the superior hemorrhoidal artery and vein (arteriovenous network).
- It is located in the submucosal layer of the rectum and drains into the inferior mesenteric vein.

Inferior Hemorrhoidal Plexus

- The anastomosis of the inferior rectal artery and vein forms the inferior hemorrhoidal plexus.
- It is located in the subcutaneous tissue (perianal space) around the anal canal and drains into the internal iliac vein (Fig. 1.24).

Surgical Significance

The engorgement of superior hemorrhoidal plexus forms the internal hemorrhoids, whereas the engorgement of inferior hemorrhoidal plexus forms the external hemorrhoids.

Anastomosis between the SHA and the IHA

Although the SHA supplies above the dentate line and the IHA below the dentate line, there is an anastomosis between them below the dentate line, which can lead to internal–external hemorrhoids (Fig. 1.25).

Surgical Significance

- The anastomosis between SHA and IHA is present below the dentate line.
- It contributes to the formation of intero-external hemorrhoids. The increased pressure in the internal plexus is one of the reasons for the formation of interno-external hemorrhoids.

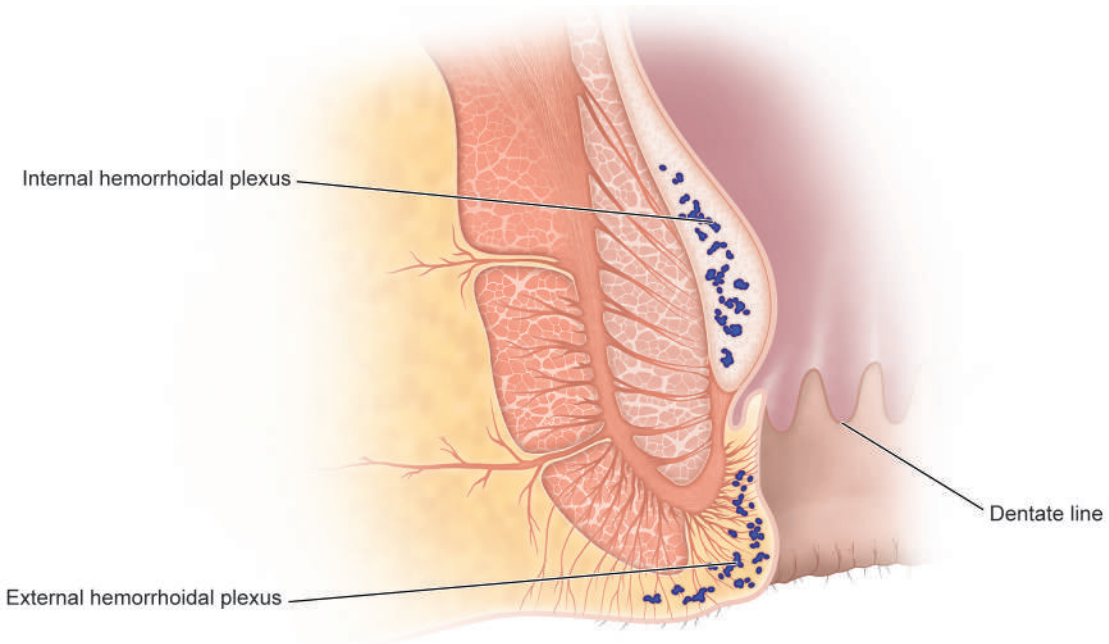


Fig. 1.24: Internal and external hemorrhoidal plexus

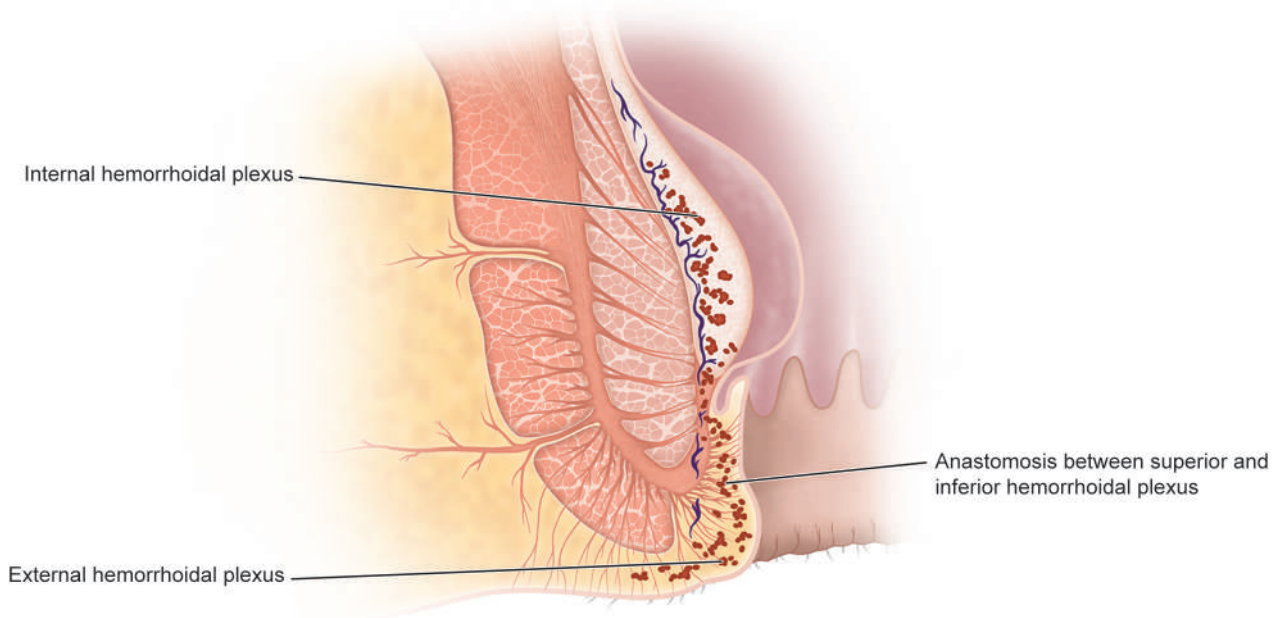


Fig. 1.25: Anastomosis between superior and inferior hemorrhoidal arteries

Correlation between Portal System and Rectal Varices

- The inferior mesenteric vein drains into the splenic vein, which joins the superior mesenteric vein to form the portal vein. The inferior and middle hemorrhoidal veins drain into the internal iliac veins, which return blood to the heart via the inferior vena cava.
- A portocaval anastomosis is formed through communication between the hemorrhoidal plexuses. However, hemorrhoidal engorgement is an uncommon occurrence. Instead, true rectal varices may develop in portal hypertension. The rectal varices are bluish longitudinal columns above the anorectal ring which extend towards the sigmoid (Figs 1.26 and 1.27).

Surgical Significance

One should always differentiate between the hemorrhoids and the rectal varices in bleeding per rectum. The rectal varices extend from the anorectal ring up to the sigmoid, and they seldom bleed. The management of these two diseases is entirely different (Fig. 1.27).

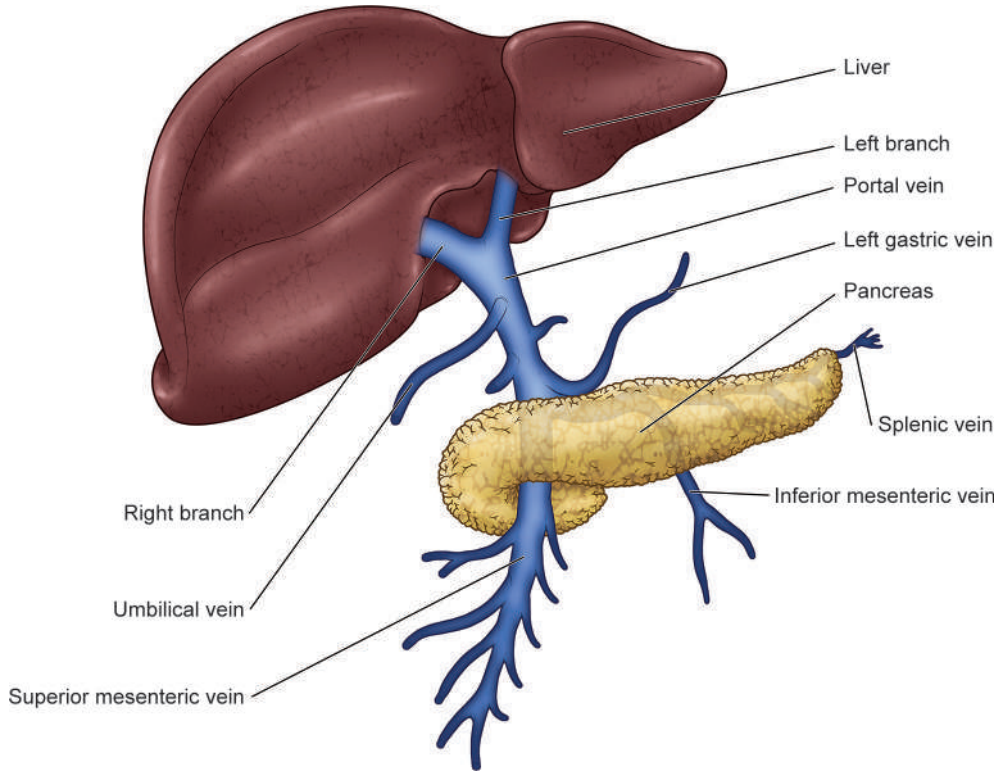


Fig. 1.26: Portal vein formation

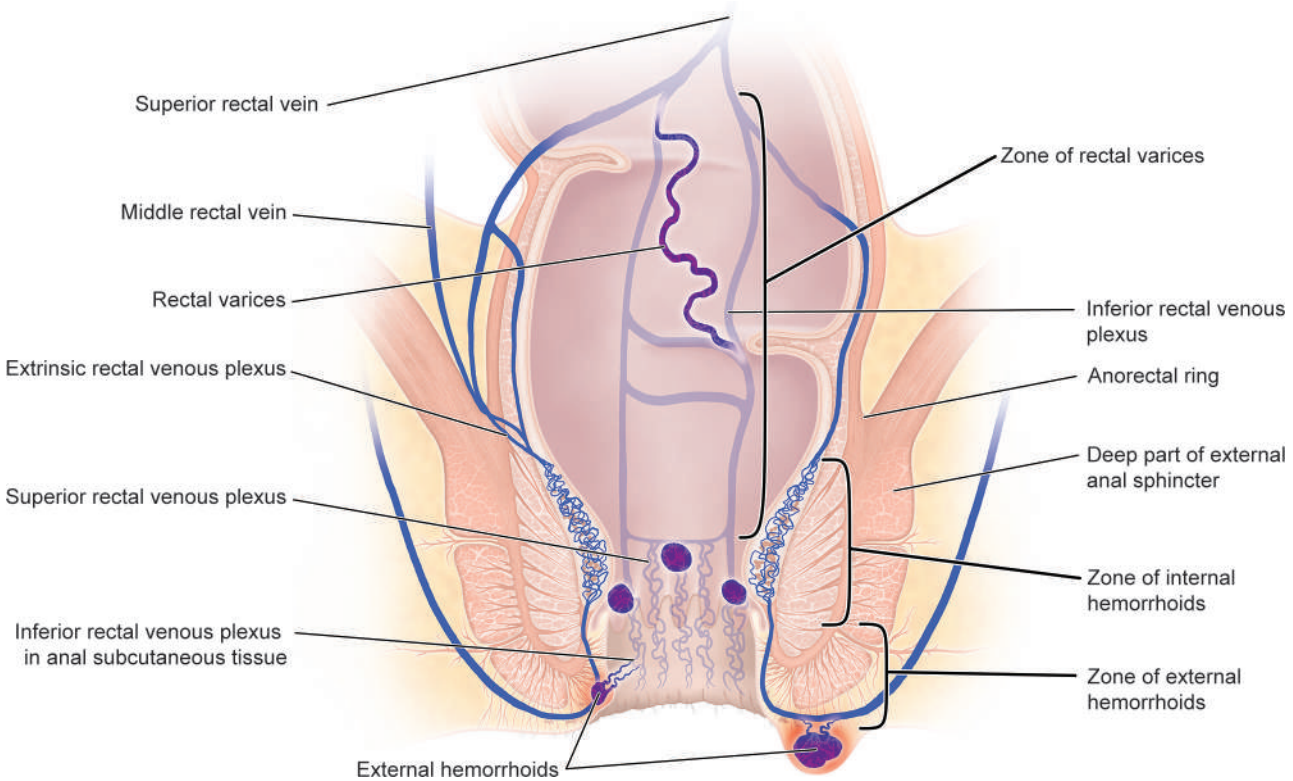


Fig. 1.27: Portal–systemic circulation in the distal part of the rectum with rectal varices

Lymphatic Drainage of Anal Canal

Above the dentate line, the lymphatics drain into the internal iliac lymph nodes and distal to the dentate line into the superficial inguinal lymph nodes (Fig. 1.28).

Surgical Significance

Since the lymphatic drainage above and below the dentate line is different, the anorectal diseases, both benign and malignant follow distinct pathways of spread.

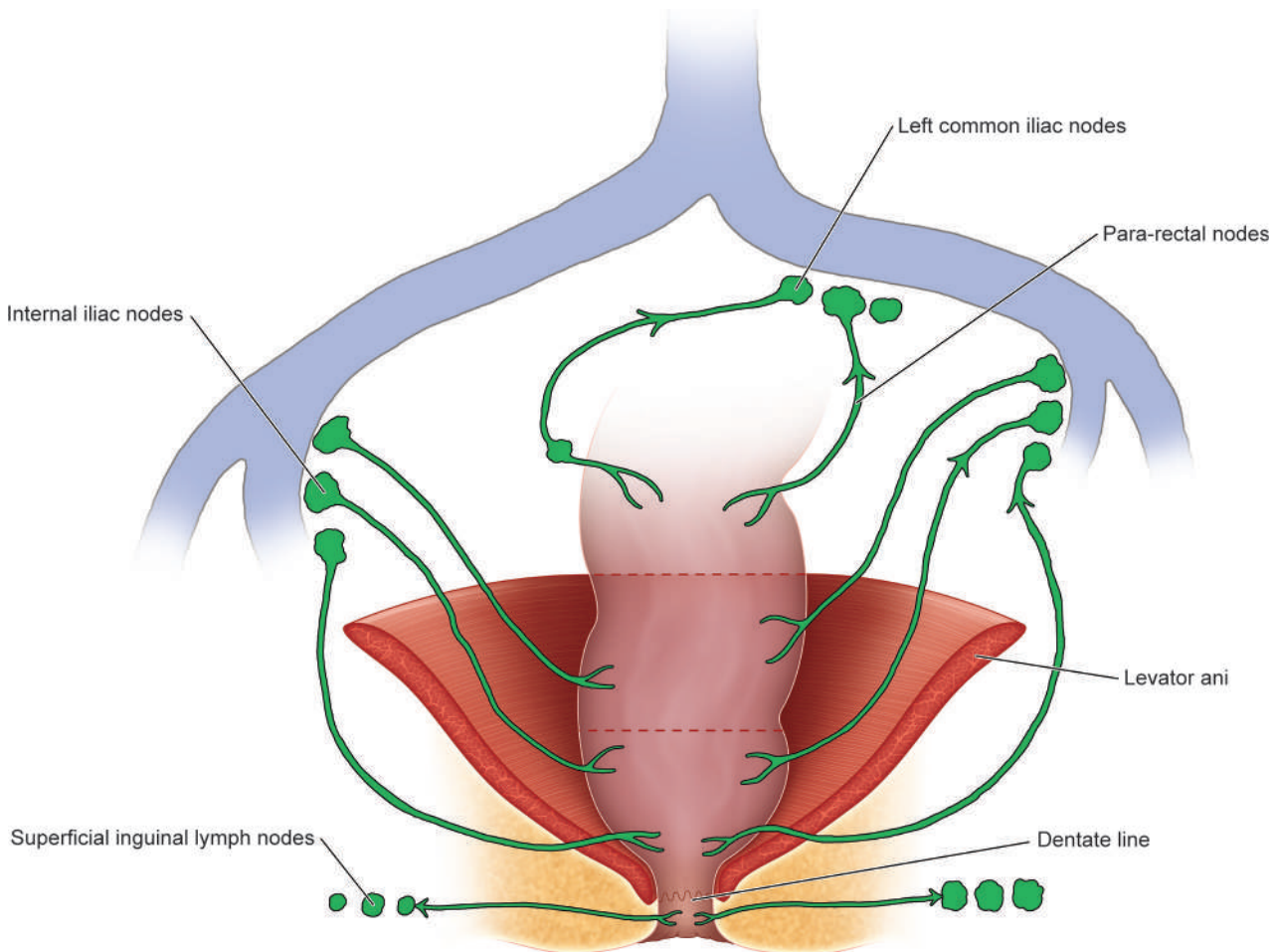


Fig. 1.28: Anal canal lymphatic drainage

Anal Canal Innervation (Fig. 1.29)

Above the Dentate Line

- Para-sympathetic (S-2, S-3, S-4)
- Sympathetic (L-5)

Below the Dentate Line

- The pudendal nerve's inferior rectal branch (S-2 and S-3)
- Perineal branch (S-4)

Surgical Significance

Since the pudendal nerve supplies the area below the dentate line, anorectal disorders like anal fissures and thrombosed external hemorrhoids are painful.

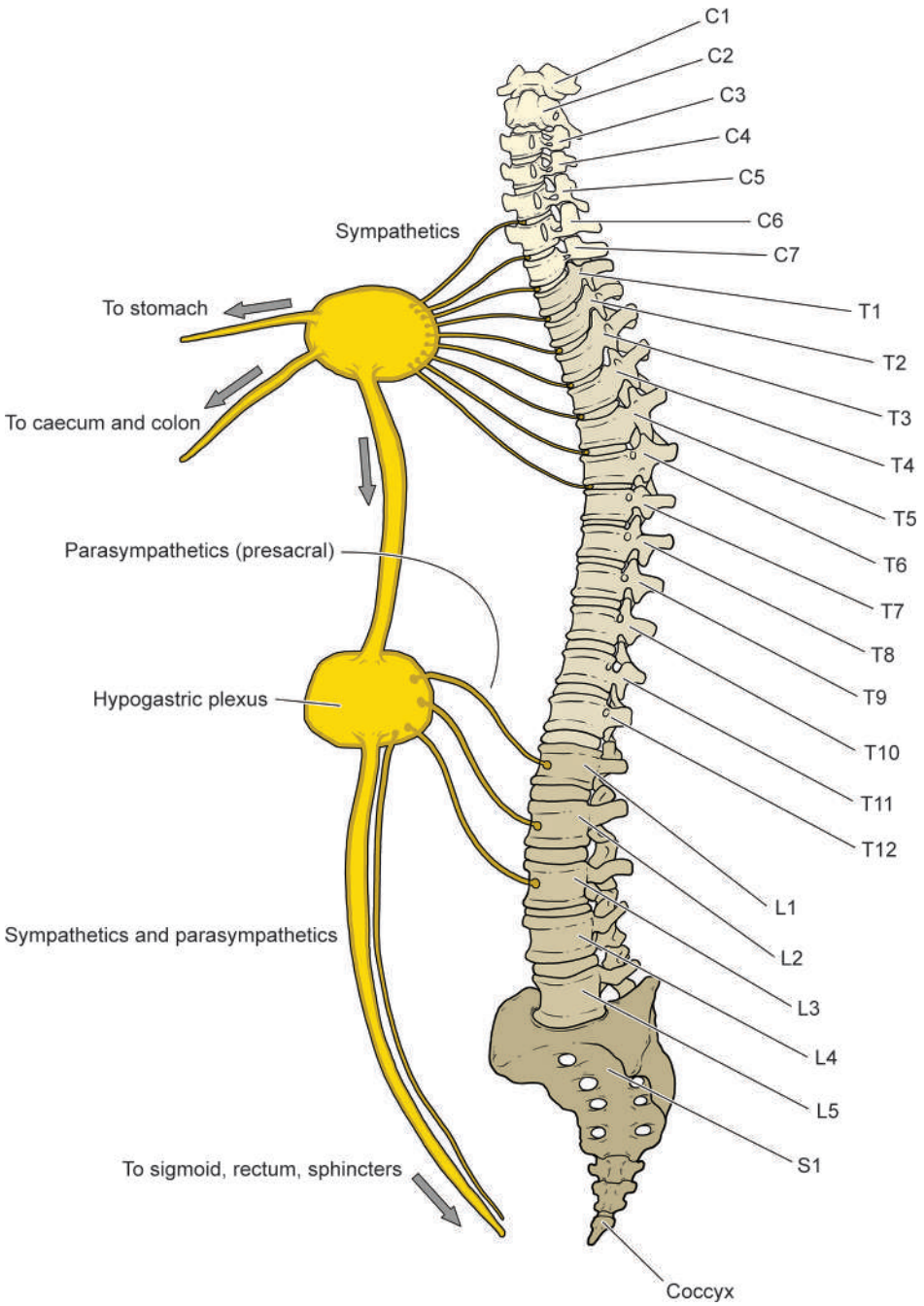


Fig. 1.29: Anal canal innervation

Anorectal Ring

The anorectal ring is formed by

- The puborectalis sling (posteriorly and laterally)
- The deep part of the external sphincter
- The fibres of the internal sphincter

It is impossible to identify these structures separately. The anorectal ring can easily be palpated by inserting a finger into the anal canal and rotating laterally like a hook at the anorectal junction (Figs 1.30 to 1.32).

Surgical Significance

- The anorectal ring plays a crucial role in maintaining continence.
- The highest part of the internal hemorrhoidal plexus lies close to the anorectal ring.
- Care must be taken to avoid injury to the anorectal ring during fistula surgeries, as it may cause fecal incontinence.

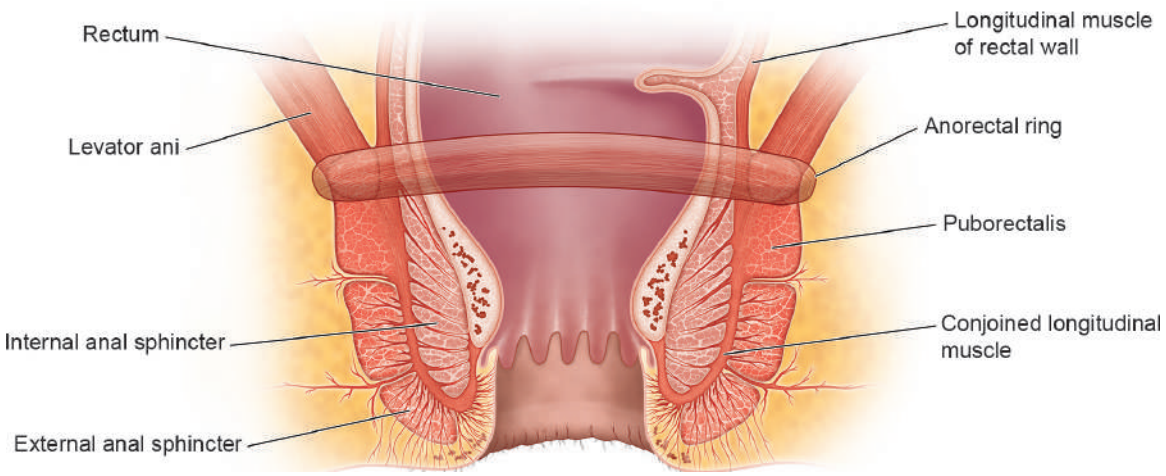


Fig. 1.30: Anorectal ring

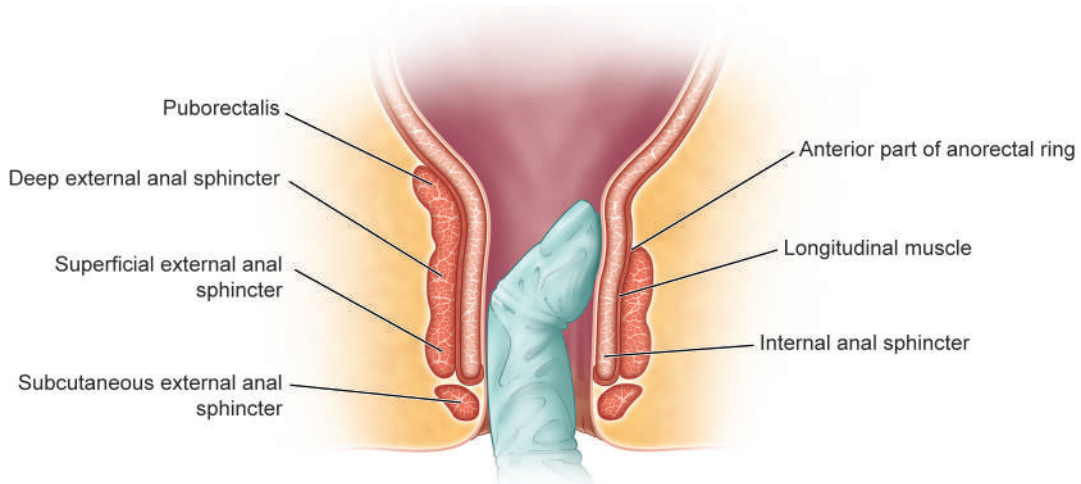


Fig. 1.31: Palpation of the anterior part of the anorectal ring

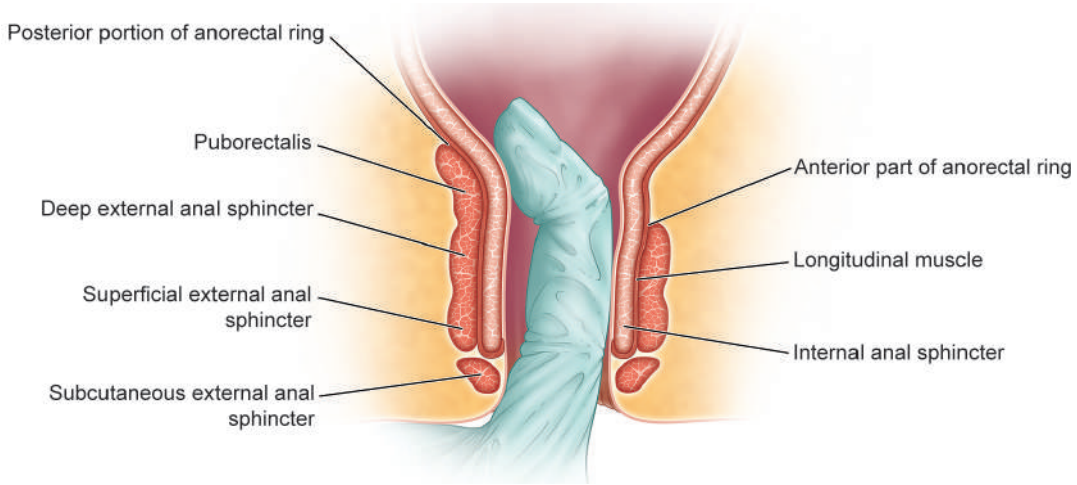


Fig. 1.32: Palpation of the posterior part of the anorectal ring

Anorectal Angle

The anorectal junction is U-shaped, formed by a puborectalis muscle sling. Usually, the anorectal angle is 90 degrees but becomes 120 degrees during defecation. The anorectal angle and the puborectalis ensure faecal continence (Fig. 1.33).

TABLE 1.2: IMPORTANT ANATOMICAL LANDMARKS DURING ANORECTAL SURGICAL PROCEDURES

Dentate line	An important landmark while treating haemorrhoids and anal fistula. The surgical procedures below the dentate line cause severe pain due to pudendal nerve innervation.
Intersphincteric groove	Serves as a marker for anal fissure during lateral internal sphincterotomy.
Anoderm	Anoderm preservation is critical during hemorrhoidectomy since its excision can result in anal stenosis.
Anal ducts and crypts	An important landmark in fistula surgery.
Anal cushions	An important structure for the development of hemorrhoids.
White line of Hilton	Point of entry of laser fibres for laser hemorrhoidoplasty.
Anorectal ring	Helps maintain continence. Surgical division during fistulotomy leads to faecal incontinence.

Conclusion

In-depth knowledge of the anatomy of the anal canal will help a surgeon understand the structures that can be sacrificed and those that must be preserved during anorectal surgical procedures. A few precautions taken during surgery can help a surgeon prevent complications.

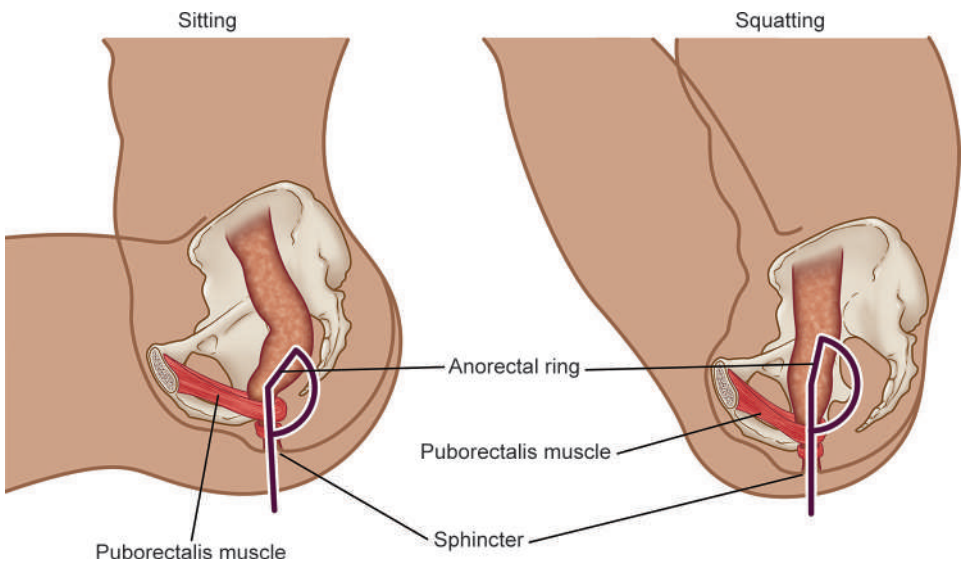


Fig. 1.33: Anorectal ring in sitting and squatting positions

Further Reading

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