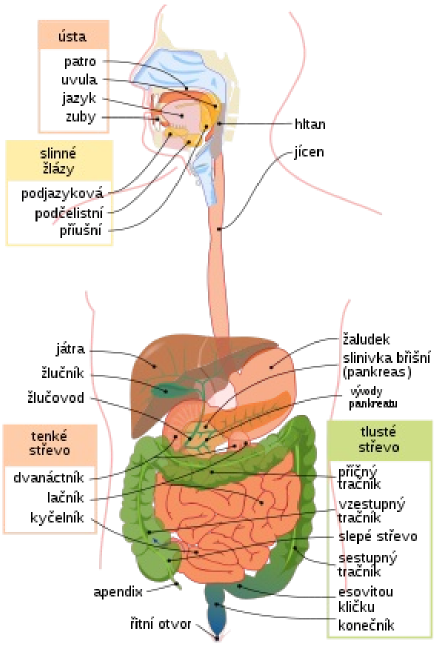
Mechanical properties of tissues - Digestive system

Except for the mouth, the upper esophagus and the external sphincter, movements are performed by smooth muscle. We find it in the wall of the digestive tube in 3 types - **Muscularis mucosae** (at the bottom - they help change the shape of the mucous membrane), in the layer of Muscularis externa in two types - **longitudinal** and **circular**. Therefore, the movements are somewhat similar in different parts of the GIT. The peristaltic reflex was discovered as early as 1899. It is a contraction above and dilation below the site of mechanical or chemical irritation of the mucosa, thereby moving the digestive tract in a distal direction. Smooth muscle cells are able to rhythmically change the membrane potential. This is called the **basal electrical rhythm** (BER or slow wave). A regular BER rhythm may not be associated with contraction because the membrane potential does not cross 0 mV. An Action potential must be exceeded for a contraction to occur. BER determines the frequency, direction and speed of propagation of peristalsis. The BER frequency is changed using Cajal cells – pacemakers that oscillate slightly faster than other cells. The frequency of BER varies in different parts of the GIT.

Biomechanics of masticatory pressure



Digestive system

The masticatory muscles are the source of the masticatory pressure force. The temporalis muscle is mainly responsible for the elevation of the mandible. The force that the adductors can develop during simultaneous contraction is given as 16-20 N, calculated for the entire dental arch. The absolute strength calculated by the physiological cross-section and the number of muscle fibers is 90 N for women and 120 N for men. The force value rises above 30 N only in stressful situations. The magnitude of the force on individual teeth depends on various factors such as the occlusal surface, the periodontal surface, the position in the arch, etc. The lower jaw is essentially a one-sided lever, with the force being applied most in the area of the 1st and 2nd molars. In the Czech Republic, the force that the adductors have to develop is usually considerably smaller due to food preparation. The ultimate compressive strength and maximum compressive load show the highest values between 30-49 years of age. Furthermore, it is found that the maximum load for the roots of the teeth of the upper jaw is higher than that of the lower jaw.

E – Young's modulus of elasticity in tension and compression (resistance to normal stress), m – Poisson's number (ratio between relative longitudinal elongation and transverse shortening)

Material	Enamel	Mineralized dentin	Dentin	Amalgam	Femur
E[GPa]	84	14,7	0,26	55	17,2
m	0,33	0,31		0,35	
Ultimate tensile strength [MPa]	10,3	105,5	29,6	48	121
Ultimate compressive strength [MPa]	384	297		353	167
Elastic limit [MPa]	353	167			
Ultimate shear strength [MPa]	90,2	138		188	

From the table, it can be seen that the strength limit of the tooth is greater in compression than in tension.

Dental restorations must be made in such a way that there is no tissue overload at the individual places of the arch. They must also be made of bioinert materials. We distinguish 3 types of transmission of chewing pressure to the bone: • **dental transmission** – to healthy surrounding teeth • **mucosal transmission** – through the mucosa of the edentulous alveolus • **combined** – From the table, it is clear that the use of amalgam in dentistry also has its physical justification – similar properties of dental tissues.

Swallowing

Swallowing can be divided according to the passage of the bite into three consecutive phases, namely the **oral** influenced by will), **pharyngeal** and **esophageal** phases. After grinding the food by chewing and mixing it with saliva, the morsel is pushed back into the oral cavity and pharynx. Here, by irritating the root of the tongue, the palatal arches and the pharynx, the swallowing reflex is triggered. When swallowing, the mouth is closed by clenching the jaws, the tongue presses on the hard palate, and the soft palate separates the nasal cavity from the pharynx. To prevent food from entering the respiratory tract, the epiglottis is bent by raising the larynx and tongue, thereby separating the Larynx and pharynx. As further protection of the airways, ventilation is suspended and the vocal cordsare closed.

- Saliva, which has several functions, plays a big role in the initial processes of food processing . They soften and smooth the surface of the bite to facilitate its processing and subsequent swallowing, thereby also protecting the mucous membrane of the oral cavity from damage. Furthermore, ptyalin enables partial digestion of starches in the mouth, if it is kept there for a long enough time. In addition, it cleans the oral cavity from food residues and, thanks to the content of calcium ions, protects tooth enamel from decalcification.

Esophagus

After the mouthful enters the Esophagus the upper esophageal sphincter reflexively contracts after a short relaxation, followed by the contraction of the esophageal muscles - **the primary peristaltic wave**. Through the mechanism of contraction behind the bite (pushing the food to the stomach) and relaxation in the area of the bite and in front of it (clearing the way), the food slowly reaches the lower esophageal sphincter (DES), which relaxes just before its arrival and closes again after its passage. If the bite stops in the esophagus, a secondary peristaltic wave accompanied by pain occurs from this point. The DES, like the upper esophageal sphincter, is strongly contracted at rest, preventing damage to the esophagus by stomach contents - it creates a reflux barrier.

- Sometimes, even in a physiological state, there are temporary relaxations of it, which occur, for example, during belching. During them, stomach contents enter the esophagus (gastroesophageal reflux), manifesting as "heartburn". Damage to the esophagus prevents its self-cleansing ability. This is aided by gravity together with peristalsis, saliva secretion and also the contraction of the DES pushing the contents back into the stomach.

Vomiting

Another form of emptying the stomach is vomiting. It is a **protective reflex**, that is supposed to remove toxic substances from the stomach that are dangerous to the body. However, longer term vomiting leads to dehydrataion and loss of H+ to metabolic alkalosis. Vomiting can be caused by distension (overfilling) of the stomach or its damage by a toxic substance (alcohol, drugs, etc.), irritation of the pharynx, the balance system in the inner ear, but also various smells and visual sensations. It is common during pregnancy, radiation, and may also have psychosomatic causes. Symptoms of impending vomiting include nausea, salivation (tooth enamel protection), paleness and sweating. The diaphragm is fixed in a slight inspiration, which increases the pressure in the abdominal cavity, and at the same time decreases it in the chest cavity. There is a contraction of the abdominal press (contraction of the muscles of the abdominal wall) and thus a further increase in intra-abdominal pressure, contraction of the duodenum, reverse peristaltic movements appear in the stomach and later in the esophagus. Relaxation opens the lower esophageal sphincter, into which the resulting pressure pushes the contents of the stomach. This is followed by the "lifting of the stomach", which is caused by the re-entry of the contents into the esophagus, which, however, does not pass through the pharynx and when the muscles of the abdominal press and diaphragm relax, it returns again to the stomach through secondary peristalsis of the esophagus. During vomiting itself, the upper esophageal sphincter opens, closes the entrance to the larynx, and the contents come out through the mouth.

Stomach

The function of the stomach is the short-term storage of food for the purpose of mechanical and chemical processing in the digestive tract, which then travels further into the small intestine. The stomach has a volume of only 50 ml at rest and on an empty stomach, but it is able to expand up to 1.5 l thanks to so-called **receptive relaxation** (when a bite enters the esophagus) and **adaptive relaxation** (with gradual filling), which reduce the muscle tone of the stomach and facilitate its filling. After the end of the intake, there is a rest phase, when the contents in the stomach are slowly arranged - liquids flow past the solid contents quickly into the duodenum, while fats, on the other hand, form an oil film on the surface of the contents. Within 1 hour, gastric peristalsis occurs, induced by a slightly increased tone in the proximal part of the stomach, which slowly moves the contents to its distal part for processing. The intensity of contractions increases towards the pylorus and at the same time also with the time that has passed since the intake of food. During the peristaltic wave, which runs through the distal part of the stomach, the pylorus closes very early and the food is crushed, mixed and ground by the continued propulsive movement that impinges on the pylorus. The bite then moves retropulsively. Stomach acid must not get into duodenum, nor bile into the stomach, therefore the pyloric sphincter precisely controls the emptying of the stomach by its contraction, narrowing or expansion. To some extent we find **coordination with the duodenum** here – the duodenum is usually relaxed when the antrum pyloric contracts. In addition (to prevent reflux from the duodenum back to the stomach) the peristaltic waves of the duodenum are at a higher frequency (duodenum approx. 10-12/min, antrum 3/min).

Small intestine

All movements of the small intestine move the chyme aborally, but not always to the same extent. They can be divided, among others, as follows:

- **Changes in tone** – varies with size and composition of chyme
- **Segmentation movements** – strangulation, helps to mix the chyme
- **Rocking movements** – contractions of the longitudinal muscles
- **Peristaltic contractions** – propulsive or non-propulsive
- **Interdigestive movements** – movements when the intestine is empty

- **Muscularis mucosae contractions** – move the mucosa and villi

These movements are influenced mainly by means of vegetative nerves and hormones.

Ileocecal sphincter

Its contraction creates a higher pressure than in the colon, which reduces the reverse flow of chyme. Stretching the colon increases the tone of the sphincter, stretching the adjacent ileum, on the other hand, leads to a decrease in tone and thus its easier penetration into the colon.

Colon

The muscle of the large intestine has a typical inner circular layer and an outer longitudinal one, which is very thin down to three stripes - taenia, which stretch along the entire length of the intestine. The muscularis mucosae layer is also very well formed. Compared to other parts of the intestine, mixing movements prevail in the ascending colon and cecum. Mixing movements are realized by contracting longitudinal muscles (swinging movements) and especially so-called **haustrations**. It is a contraction of the circular muscle of two places a few centimeters apart, which are about 2.5 cm wide. The taenia will also contract and bulge. Holzknecht's big movements occur one to three times a day. All haustrations are dampened, then contraction of the circular muscle occurs gradually from the oral end, and thus a more pronounced shift of the stool. This process takes about 30 min. The rate of passage of undigested particles through the entire intestine usually takes 2-3 days. Indigestible food components increase the speed of passage and thus the motility of the large intestine due to their volume.

Defecation

The processed intestinal content fills the sigmoid colon, the rectum is still empty. The passage of contents into the rectum accompanied by pressure causes the ampulla recti to expand, which **reflexively** causes relaxation of the internal sphincter (sphincter ani internus) and at the same time contraction of the striated external sphincter (sphincter ani externus). Relaxation of the external sphincter is followed by a reflex contraction of the rectal muscles, a large peristaltic wave is created, which pushes the contents further into the anus and expels it. Expulsion of the stool is supported by the activity of the abdominal press by increasing the intra-abdominal pressure by the contraction of the abdominal muscles associated with the previous deep inhalation. The interplay of all these factors and the opening of **both sphincters** result in efficient emptying. Defecation does not occur if the external sphincter is not open. If it is not opened within a few minutes, the reflex goes out.

Links

Related Articles

- Digestive system
- Gastroesophageal reflux (pediatrics)
- Esophageal reflux disease

External links

- Digestive System (Wikipedia) (https://cs.wikipedia.org/wiki/Trávicí_soustava_člověka)
- Swallowing (imaging with MRI) (https://www.youtube.com/watch?v=0MoJPhClfYc)

Resources

- TROJAN, Stanislav, et al. Medical Physiology. 4th edition. Prague: Grada, 2003. 772 pp. ISBN 80-247-0512-5.
- NAVRÁTIL, Leoš and Jozef ROSINA, et al. Medical Biophysics. 1st edition. Prague: Grada, 2005. 524 pp. ISBN 80-247-1152-4.
- CIHÁK, Radomír and Miloš GRIM. Anatomy 2. Second Edition. Prague: Grada, 2002. 488 pp. 127-138. ISBN 80-247-0143-X.
- HAMPL, Václav, Institute of Physiology UK 2.LF. Motility of the digestive tract - lecture notes [online] Available at: <http://physiology.lf2.cuni.cz/teaching/pohyby_git/index.htm>