Chapter

Anti-Obesity Medical Devices

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Abstract

Obesity is a major health problem worldwide responsible for increased morbidity/mortality and high cost for the society. Management of obesity requires multidisciplinary approaches including diet, food supplement, exercise, behavior change, drug, medical device, gut microbiome manipulation, and surgery. Anti-obesity medical devices are an option for subjects who have not responded to more conservative medical treatments but want an alternative to surgery. Compared to bariatric surgery, they have the advantage of being less invasive, easier to perform, and reversible. In the United States of America (USA), based on the expected weight loss, the Center for Devices and Radiological Health (CDRH) of the Food and Drug Administration (FDA) categorizes anti-obesity medical devices as weight-loss devices or weight-management devices. The weight-loss devices include gastric band devices, gastric space-occupying devices, and gastric emptying devices. The weight-management devices include oral removable palatal space-occupying devices and ingested transient gastric space-occupying devices. The effectiveness, safety, and cost of anti-obesity medical devices vary considerably by the type of medical device. Their use should always be combined with lifestyle changes. Considering the large market size of obesity treatment, anti-obesity medical devices can play a major role in the management of obesity.

Keywords: medical devices, obesity, weight loss, weight management

1. Introduction

Obesity is excess body weight for a given height, defined by a body mass index (BMI) $\geq$ 30 kg/m^2. In some Asian countries (e.g., Japan), the threshold to define obesity is lower (25 kg/m^2). Obesity is a major health problem worldwide associated with increased morbidity/mortality and high cost for the society. The prevalence of obesity has doubled in more than 70 countries since 1980. The number of adult subjects with obesity is around 700 million worldwide. Nearly 4 million subjects die each year from the consequences of obesity. The annual cost of obesity is more than $2 trillion [1–3].

Management of obesity requires multidisciplinary approaches including diet, food supplement, exercise, behavior change, drug, medical device, gut microbiome manipulation, and surgery [1, 4–9]. The annual obesity treatment market is around $6 billion. In the USA, among subjects with obesity, only 2% receive drug therapy and less than 1% who are eligible for bariatric surgery benefits from it. The reasons for these undertreatment rates are mainly related to adverse effects/complications and cost of drugs and bariatric surgery.

Medical devices available 100 years ago were limited to stethoscope, original medical X-ray imaging device, and electrocardiograph [10]. Over the past several

decades, the number of medical devices has increased exponentially. Anti-obesity medical devices are positioned to bridge the gap between more conservative treatments (e.g., lifestyle) and more aggressive interventions (e.g., bariatric surgery). Compared to bariatric surgery, they have the advantage of being less invasive, easier to perform, and reversible. Anti-obesity medical devices are available upon prescription or as over-the-counter products.

2. Heterogeneity of anti-obesity medical devices

Anti-obesity medical devices represent a heterogeneous family of devices in terms of presentation, usage/administration, mechanism of action, effectiveness, safety, regulation, availability, and cost [8, 11–14]. The devices can be as different as an intragastric balloon, a stomach aspiration system, or particles administered orally in capsule.

3. General characteristics of anti-obesity medical devices

Unlike anti-obesity drugs that act chemically through specific receptors, anti-obesity medical devices act rather mechanically. They do not have systemic absorption, specific metabolism, or receptors. Their research and development pattern follow specific models. The terminology used for medical devices differs slightly from that used for drugs (e.g., sham instead of placebo, effectiveness instead of efficacy). With some medical devices, it is not possible to use a sham for ethical and/or technical reasons. Compared to drugs, medical devices have different effectiveness dynamics. Unlike drugs, for some anti-obesity medical devices, there is no compliance issue with the device use since the device is placed in the body for several months and there is no need for repeated administration that might be affected by the subject's discipline. Because there is no systemic absorption, there are no side effects related to the impact of medical devices on different organs through the bloodstream. The regulatory systems ruling anti-obesity medical devices are based on short product life cycles. The marketing and sales of anti-obesity medical devices are based on different models as compared to drugs.

4. Mechanism of action of anti-obesity medical devices

Anti-obesity medical devices can cause weight loss through different mechanisms by acting at different levels.

4.1 Decrease in food intake

Although the primary impact of the anti-obesity medical devices is mechanical, the final effect may be achieved through changes in several factors controlling appetite and food intake, especially the gastrointestinal hormones (e.g., decrease in ghrelin, increase in glucagon-like peptide-1).

4.1.1 Oral cavity

An anti-obesity medical device can decrease the food intake by limiting the bite size in the oral cavity.

4.1.2 Stomach

An anti-obesity medical device can decrease the food intake by reducing the available stomach volume.

4.1.3 Others

Other levels of impact to achieve food intake reduction are possible and have been or will be investigated.

4.2 Decrease in available/absorbed nutrient

4.2.1 Stomach

An anti-obesity medical device can decrease the amount of available nutrient by removing part of the gastric contents.

4.2.2 Intestine

An anti-obesity medical device can decrease the absorbed nutrient by bypassing part of the intestine.

5. Challenges in developing anti-obesity medical devices

The main challenges in the development of anti-obesity medical devices are due to lack of unique regulatory guidance and disparities in time and cost of approval processes in different countries.

6. Regulation and approval/clearance of anti-obesity medical devices

The regulation of anti-obesity medical devices varies by countries or group of countries. There are important differences in the regulatory processes, cost, and time to approval between the USA and Europe [15].

Over-the-counter anti-obesity medical devices may or may not need regulation and approval/clearance depending on the devices and countries.

6.1 USA

In the USA, the regulation of medical devices is centralized since 1976 through the FDA. This centralized process allows a better coordination and enforcement of rules. The CDRH is in charge of approval/clearance of anti-obesity medical devices. There are three regulatory classes of medical devices: Class I (low risk), Class II (moderate risk), and Class III (high risk). Based on the expected weight loss, two categories of anti-obesity medical devices have been defined: weight-loss devices ("more" weight loss) and weight-management devices ("less" weight loss). The approval/clearance is through premarket notification process [510(k)] or premarket approval (PMA) process and is based on safety and effectiveness.

A new guidance using benefit-risk approaches is in preparation by the CDRH taking into account the weight loss (extent and duration), the rate of responders (≥ 5% weight loss), the reduction of comorbidities (e.g., hypertension, dyslipidemia, type 2 diabetes), and the safety [rate and severity of adverse events (AEs)].

6.2 Europe

Since its formation in 1993, the European Union (EU), currently a group of 27 countries (after the recent removal of the United Kingdom), has established rules for the approval of medical devices. Anti-obesity medical devices are regulated under directive 93/42/EC. There are four regulatory classes of medical devices: Class I (low risk), Class IIa (low-moderate risk), Class IIb (moderate-high risk), and Class III (high risk). Each member country has a regulatory entity called Competent Authority (CA). The CA certifies/notifies entities called Notified Bodies (NBs) in each country. The NBs are private, for-profit companies responsible for conformity assessment and CE (Conformité Européenne) mark. There are over 50 NBs in the EU. The NBs contract with the manufacturers to supply the CE mark and the approval is based on safety and performance. Clinical effectiveness is not a requirement. An anti-obesity medical device with a CE mark can be marketed in any EU member country.

In the EU, the approval process is more flexible, faster, and less expensive in comparison to the USA.

6.3 Other countries

Other countries have different regulatory procedures. The approval process has varying degrees of sophistication and challenges. In Japan for example, the application is processed by the Pharmaceutical and Medical Device Agency (PMDA). Although the Japanese market is very attractive for foreign manufacturers, the approval process is complicated, long, and expensive due to multiple factors (e.g., lack of translated documents from Japanese, need to perform specific and costly studies in the Japanese population).

Several countries accept the FDA approval/clearance or the CE mark.

7. Approved/cleared anti-obesity medical devices

Several anti-obesity medical devices have been approved/cleared in the USA, in the EU, and in other countries. Some devices have been approved first in the EU before being approved several years later in the USA. This section focuses on anti-obesity medical devices regulated in the USA.

Below are the anti-obesity medical devices approved/cleared in the USA (**Table 1**). Their use should always be in conjunction with lifestyle recommendations on diet and exercise.

Medical device	Approval date	Indication
Lap-Band®	June 5, 2001	Weight-loss device (BMI ≥ 35 kg/m^2)
Orbera™ Intragastric Balloon System	August 5, 2015	Weight-loss device (BMI 30–40 kg/m^2)
AspireAssist®	June 14, 2016	Weight-loss device (BMI 35–55 kg/m^2)
Obalon Balloon System	September 8, 2016	Weight-loss device (BMI 30–40 kg/m^2)
SmartByte Device	May 18, 2017	Weight-management device (BMI 27–35 kg/m^2)
Plenity™	April 12, 2019	Weight-management device (BMI 25–40 kg/m^2)
TransPyloric Shuttle	April 16, 2019	Weight-loss device (BMI 30–40 kg/m^2)

Table 1.
Approved/cleared anti-obesity medical devices in the USA ranked by approval date.

7.1 Weight-loss devices

7.1.1 Gastric band devices

7.1.1.1 Lap-Band®

Lap-Band® (BioEnterics Corporation) is an adjustable silicone band placed laparoscopically around the proximal stomach immediately below the gastro-esophageal junction and attached to a subcutaneous reservoir (**Figure 1**). The level of pressure is adjusted by varying the amount of fluid that is inserted into the band. The technique is reversible, has low procedural risk, and can be performed in an outpatient setting. Lap-Band® can be revised and/or replaced as needed. The pressure imposed to the proximal stomach causes early satiety and a decrease in food intake with subsequent weight loss [8].

In the pivotal study, 292 subjects (247 females, 45 males, mean BMI = 47.4 kg/m^2) were implanted with Lap-Band® and had follow-up evaluations for 36 months. The primary effectiveness endpoint, assessed in the per protocol population at Month 36, was the excess weight loss. Safety analysis also included an additional seven subjects who previously received a similar device. At Month 36, the excess weight loss was 36.2%, relatively stable over the previous 18 months (the weight loss was 18.0%). AEs were observed in 266 subjects (89.0%). Most AEs were of gastrointestinal origin (mainly nausea/vomiting, gastroesophageal reflux, and abdominal pain, mild in the majority of cases). Serious AEs (SAEs) were observed in 16 subjects (5.4%), mainly port leakage and 2 deaths (unrelated to device).

Overall, Lap-Band® is relatively safe and has a strong effectiveness. The device was approved by the FDA in June 2001. It is indicated for weight loss in severe obesity with BMI $\geq$ 40 kg/m^2 or obesity with BMI $\geq$ 35 kg/m^2 in the presence of one or more severe comorbidities, in conjunction with lifestyle recommendations, in subjects who failed to respond to diet, exercise, and behavior change. It is contraindicated in several conditions including pregnancy, non-adult subjects, inflammatory diseases of the gastrointestinal tract, upper gastrointestinal bleeding conditions,

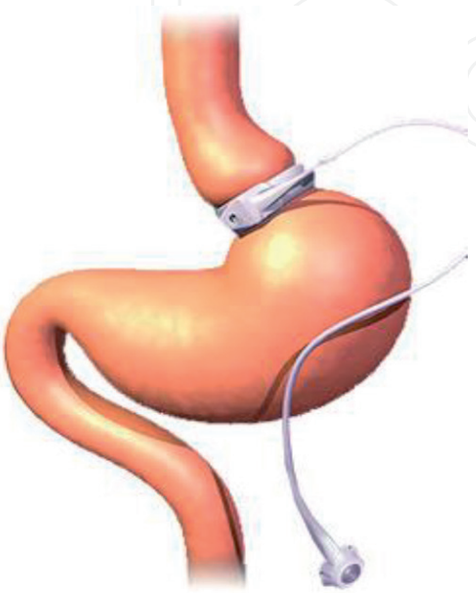

Figure 1.
Lap-Band® (BioEnterics Corporation—Picture downloaded from the internet).

portal hypertension, and severe cardiopulmonary diseases (non-exhaustive list). Complications include proximal gastric enlargement, erosion or migration of the band, and leaks of the band system (non-exhaustive list).

7.1.2 Gastric space-occupying devices

7.1.2.1 Orbera™ Intragastric balloon system

Orbera™ Intragastric Balloon System (Apollo Endosurgery, Inc.) is a balloon made of silicone placed endoscopically in the stomach (**Figure 2**). The balloon is filled with saline mixed with methylene blue (450–700 mL). The methylene blue is a marker for balloon dysfunction. In case of balloon rupture, the methylene blue will be systematically absorbed and change the color of urine to blue. The procedure is minimally invasive and can be performed in an outpatient setting. The balloon is removed endoscopically after 6 months. By occupying gastric volume, Orbera™ Intragastric Balloon System causes early satiety and a decrease in food intake with subsequent weight loss [8, 11, 13, 14].

In the pivotal study, 255 subjects (229 females, 26 males, mean BMI = 35.3 kg/m^2) were randomized into Orbera™ Intragastric Balloon System (n = 125) or control (no intragastric intervention, n = 130) arms for 6 months and 6 months follow-up after Orbera™ Intragastric Balloon System removal. Safety analysis also included an additional 35 run-in, non-randomized subjects who received Orbera™ Intragastric Balloon System. All subjects were given lifestyle recommendations. The co-primary effectiveness endpoints, assessed in the modified intention-to-treat (mITT) population at Month 9, were the excess weight loss in Orbera™ Intragastric Balloon System arm and a significantly greater weight loss in Orbera™ Intragastric Balloon System arm compared to control arm. At Month 9, the excess weight loss was 26.5% in Orbera™ Intragastric Balloon System arm, and the weight losses were 9.1 and 3.4% in Orbera™ Intragastric Balloon System and control arms, respectively. The study did not meet the first co-primary effectiveness endpoint but met the second co-primary effectiveness endpoint. At Month 6, the weight losses were 10.2 and 3.3% in Orbera™ Intragastric Balloon System and control arms, respectively. A total of 810 device-related AEs was observed (mainly nausea/vomiting, gastroesophageal reflux, and abdominal pain, mild or moderate in the majority of cases). Fourteen device- or procedure-related SAEs were observed, mainly device intolerance but no death.

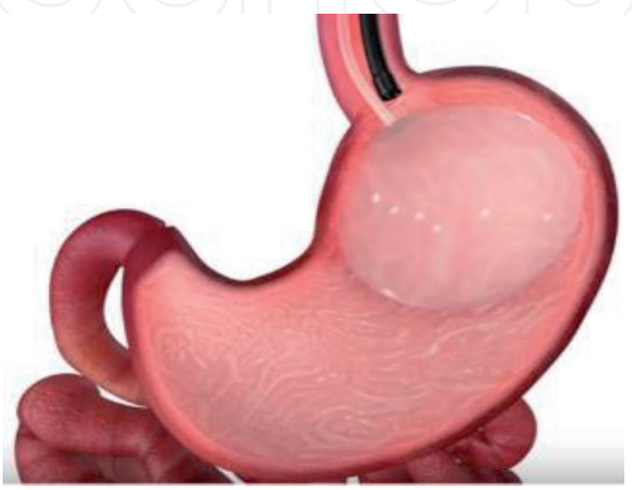

Figure 2.
Orbera™ Intragastric Balloon System (Apollo Endosurgery, Inc.—Picture downloaded from the internet).

Overall, Orbera™ Intragastric Balloon System is relatively safe and has a strong effectiveness. The device was approved by the FDA in August 2015. It is indicated for weight loss in obesity with BMI between 30 and 40 kg/m^2, in conjunction with lifestyle recommendations, in subjects who failed to respond to diet, exercise, and behavior change. It is contraindicated in several conditions including pregnancy, non-adult subjects, prior bariatric surgery, inflammatory diseases of the gastrointestinal tract, upper gastrointestinal bleeding conditions, and liver deficiency (non-exhaustive list). Complications include balloon migration, intestinal obstruction, gastric ulcer, and gastric perforation (non-exhaustive list).

7.1.2.2 Obalon Balloon System

Obalon Balloon System (Obalon Therapeutics, Inc.) is a swallowable balloon made of nylon and polyethylene contained within a gelatin capsule (attached to a thin inflation catheter) that is taken orally. The correct position of the capsule is confirmed with fluoroscopy. The capsule disintegrates in the stomach and releases the balloon. The balloon is filled with air (250 cc of nitrogen and sulfur hexafluoride gas mixture). Up to three balloons can be placed in the same session or sequentially over a 6-month period (**Figure 3**). The procedure is minimally invasive and can be performed in an outpatient setting without endoscopy. The balloon is removed endoscopically after 6 months. By occupying gastric volume, Obalon Balloon System causes early satiety and a decrease in food intake with subsequent weight loss [8, 13, 14].

In the pivotal study, 387 subjects (341 females, 46 males, mean BMI = 35.2 kg/m^2) were randomized into Obalon Balloon System (n = 198) or control (sham capsule, n = 189) arms for 6 months. At Month 6, the eligible control arm subjects were permitted to crossover and receive Obalon Balloon System for 6 months. All subjects were given lifestyle recommendations. The co-primary effectiveness endpoints, assessed in the mITT population at Month 6, were a significantly greater weight loss in Obalon Balloon System arm compared to control arm (super-superiority) and the responder rate at 5% weight loss in Obalon Balloon System arm. Device-related safety analysis also included 138 subjects who switched at Month 6 from control to Obalon Balloon System. At Month 6, the weight losses were 6.6 and 3.4% in Obalon Balloon System and control arms, respectively, and the responder rate at 5% weight loss in Obalon Balloon System arm was 62.1%. The study met both co-primary effectiveness endpoints. Most device-related AEs were of gastrointestinal origin (mainly abdominal pain and nausea/vomiting, mild in the majority of cases), observed in

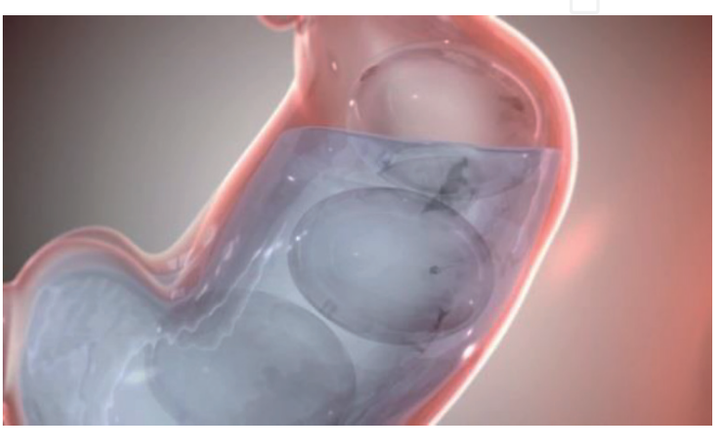

Figure 3.
Obalon Balloon System (Obalon Therapeutics, Inc.—Picture downloaded from the internet).

300 subjects (89.3%). Device- or procedure-related SAEs were observed in one subject (0.3%), a case of peptic ulcer disease.

Overall, Obalon Balloon System is relatively safe and has a modest effectiveness. The device was approved by the FDA in September 2016. It is indicated for weight loss in obesity with BMI between 30 and 40 kg/m^2, in conjunction with lifestyle recommendations, in subjects who failed to respond to diet, exercise, and behavior change. It is contraindicated in several conditions including pregnancy, non-adult subjects, prior bariatric surgery, inflammatory diseases of the gastrointestinal tract, gastric diseases, and eating disorders (non-exhaustive list). Complications include balloon migration, intestinal obstruction, gastric ulcer, and gastric perforation (non-exhaustive list).

7.1.2.3 TransPyloric Shuttle

TransPyloric Shuttle (BAROnova, Inc.) is a device placed endoscopically in the stomach (**Figure 4**). It is not strictly a balloon but functions like a balloon. It has two asymmetrical bulbs made of silicone connected by a flexible catheter. The procedure is minimally invasive and can be performed in an outpatient setting. The shuttle is removed endoscopically after 12 months. By creating intermittent obstruction to gastric outflow that delays gastric emptying, TransPyloric Shuttle causes early satiety and a decrease in food intake with subsequent weight loss [8, 13].

In the pivotal study, 270 subjects (252 females, 18 males, mean BMI = 36.6 kg/m^2) were randomized into TransPyloric Shuttle (n = 181) or control (sham endoscopic procedure, n = 89) arms for 12 months. The TransPyloric Shuttle was successfully placed in 171 subjects. The study also included an additional 32 open-label subjects who received TransPyloric Shuttle. All subjects were given lifestyle recommendations. The co-primary effectiveness endpoints, assessed in the per protocol population at Month 12, were a significantly greater weight loss in TransPyloric Shuttle arm compared to control arm and the responder rate at 5% weight loss in TransPyloric Shuttle arm. At Month 12, the weight losses were 9.5 and 2.8% in TransPyloric Shuttle and control arms, respectively, and the responder rate at 5% weight loss in TransPyloric Shuttle arm was 66.8%. The study met both co-primary effectiveness endpoints. Most device-related AEs were of gastrointestinal origin (mainly nausea/vomiting, abdominal pain, and dyspepsia, mild or moderate in the majority of

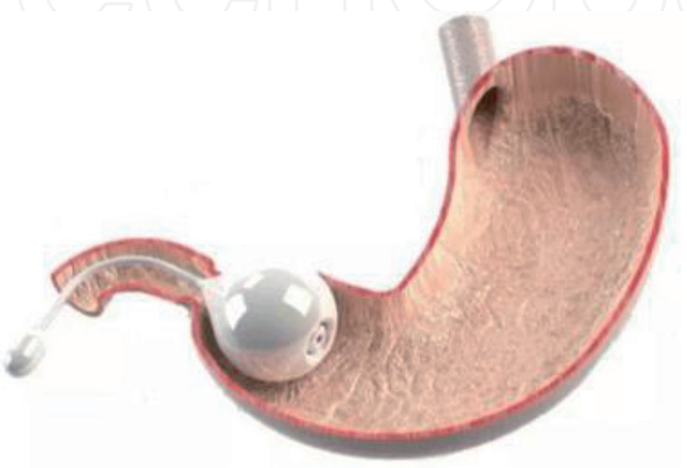

Figure 4.
TransPyloric Shuttle (BAROnova, Inc.—Picture downloaded from the internet).

cases), observed in 200 subjects (98.5%). Device- or procedure-related SAEs were observed in six subjects (3.0%), mainly device impaction but no death.

Overall, TransPyloric Shuttle is relatively safe and has a strong effectiveness. The device was approved by the FDA in April 2019. It is indicated for weight loss in obesity with BMI between 35 and 40 kg/m^2 or obesity with BMI between 30 and < 35 kg/m^2 in the presence of one or more comorbidities, in conjunction with lifestyle recommendations, in subjects who failed to respond to diet, exercise, and behavior change. It is contraindicated in several conditions including pregnancy, non-adult subjects, prior bariatric surgery, inflammatory diseases of the gastrointestinal tract, gastric diseases, and eating disorders (non-exhaustive list). Complications include device impaction and gastric ulcer (non-exhaustive list).

7.1.3 Gastric emptying devices

7.1.3.1 AspireAssist®

AspireAssist® (Aspire Bariatrics, Inc.) is a device attached to a percutaneous endoscopic gastrostomy tube implanted endoscopically (**Figure 5**). It allows the aspiration of gastric contents 20–30 minutes after each major meal (a meal containing more than 200 calories). Thorough chewing of food is required to facilitate aspiration with the 6-mm-diameter tube. The procedure is minimally invasive and can be performed in an outpatient setting. The device is removed when the desired body weight is reached. By allowing the removal of approximately 30% of ingested calories over 5–10 minutes, AspireAssist® causes decreased absorption of gastrointestinal nutrients with subsequent weight loss [8, 11–14].

In the pivotal study, 171 subjects (149 females, 22 males, mean BMI = 41.6 kg/m^2) were randomized into AspireAssist® (n = 111) or control (no intragastric intervention, n = 60) arms for 12 months. All subjects were given lifestyle recommendations. The co-primary effectiveness endpoints, assessed in the mITT population at Month 12, were a significantly greater excess weight loss in AspireAssist® arm compared to control arm (super-superiority) and the responder rate at 25% excess weight loss in AspireAssist® arm. At Month 12, the excess weight losses were 31.5 and 9.8% in AspireAssist® and control arms, respectively, and the responder rate at 25% excess weight loss in AspireAssist® arm was 56.8%. The study met the first co-primary effectiveness endpoint but not the second co-primary effectiveness endpoint. At Month 12, the weight losses were 12.1 and 3.6% in AspireAssist® and

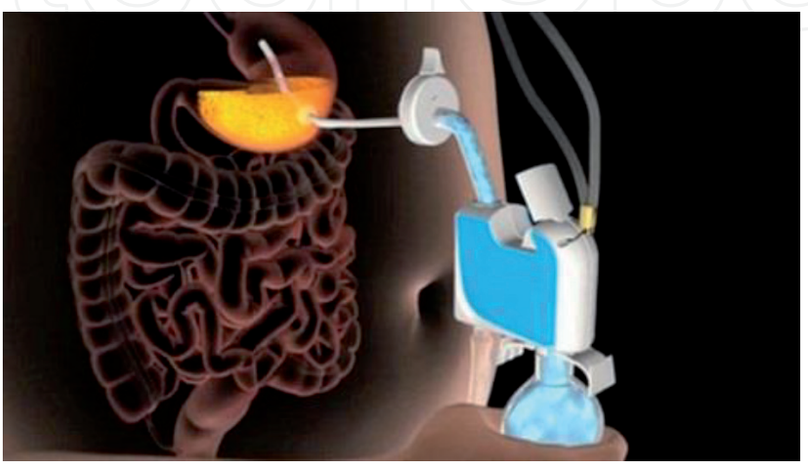

Figure 5.
AspireAssist® (Aspire Bariatrics, Inc.—Picture downloaded from the internet).

control arms, respectively. Device- or procedure-related AEs were observed in 93 subjects (83.8%, mainly peristomal granulation tissue, abdominal pain, and nausea/vomiting, mild in the majority of cases). Device- or procedure-related SAEs were observed in four subjects (3.6%), including peritonitis but no death.

Overall, AspireAssist® is relatively safe and has a strong effectiveness. The device was approved by the FDA in June 2016. It is indicated for weight loss in obesity with BMI between 35 and 55 kg/m^2, in conjunction with lifestyle recommendations, in subjects who failed to respond to non-surgical weight-loss therapy. It is contraindicated in several conditions including pregnancy, non-adult subjects, upper gastrointestinal bleeding conditions, chronic abdominal pain, severe cardiopulmonary diseases, and eating disorders (non-exhaustive list). Complications include skin irritation, infection, and electrolyte abnormalities (non-exhaustive list).

7.2 Weight-management devices

7.2.1 Oral removable palatal space-occupying devices

7.2.1.1 SmartByte Device

SmartByte Device (Scientific Intake) is an oral device occupying space on the upper palate. It includes a temperature-recording sensor to monitor usage (**Figure 6**). It is worn in mouth during meal consumption. The device is renewed every 12 months. By creating limited bite size and slower eating, SmartByte Device causes a decrease in food intake with subsequent weight loss [16].

In the pivotal study, 173 subjects (BMI between 26 and 36 kg/m^2) were randomized into SmartByte Device (n = 102) or control (no oral intervention, n = 71) arms for 4 months. All subjects were given lifestyle recommendations. The primary effectiveness endpoint, assessed in the ITT population at Month 4, was a greater responder rate at 5% weight loss in SmartByte Device arm compared to control arm. At Month 4, the responder rates at 5% weight loss were 20.6 and 5.6% in SmartByte Device and control arms, respectively. The study did not meet the primary effectiveness endpoint. At Month 4, the weight losses were 1.7 and 0.4% in SmartByte Device and control arms, respectively. Device-related AEs were observed in five subjects (4.9%, including two episodes of transient choking on food). No device-related SAEs were observed.

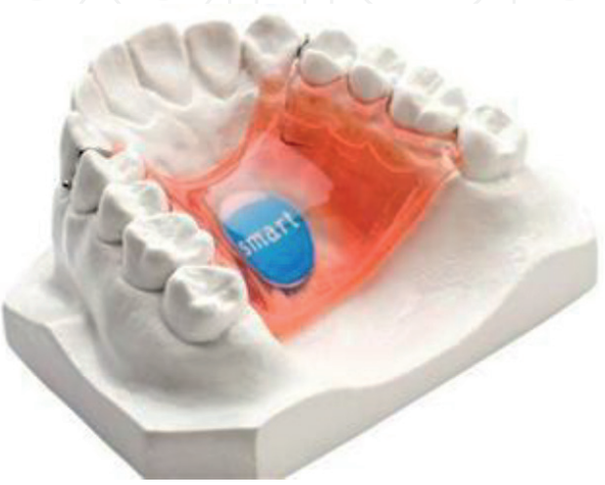

Figure 6.
SmartByte Device (Scientific Intake—Picture downloaded from the internet).

Overall, SmartByte Device is safe and has a weak effectiveness. The device was cleared by the FDA in May 2017. It is indicated to aid in weight management in overweight and obesity with BMI between 27 and 35 kg/m^2, in conjunction with lifestyle recommendations. It is contraindicated in pregnancy and eating disorders. Complications include choking on food and mouth soreness (non-exhaustive list).

7.2.2 Ingested transient gastric space-occupying devices

7.2.2.1 Plenity™

Plenity™ (Gelesis, Inc.) is a superabsorbent hydrogel (cellulose and citric acid, forming a three-dimensional matrix) administered orally in capsules with 500 mL of water (three capsules, 20–30 minutes before lunch and dinner). The hydrogel particles hydrate up to 100 times their initial weight in the stomach and intestine (**Figure 7**). The particles mix with ingested food and create a larger volume with higher elasticity and viscosity. The particles degrade in the colon and are eliminated in the feces. By creating a larger volume with higher elasticity in the stomach and intestine, Plenity™ causes early satiety and a decrease in food intake with subsequent weight loss [17].

In the pivotal study, 436 subjects (245 females, 191 males, mean BMI = 33.8 kg/m^2) were randomized into Plenity™ (n = 223) or control (sham capsule, n = 213) arms for 6 months. All subjects were given lifestyle recommendations. The co-primary effectiveness endpoints, assessed in the ITT population (multiple imputation) at Month 6, were a significantly greater weight loss in Plenity™ arm compared to control arm (superiority) and the responder rate at 5% weight loss in Plenity™ arm. At Month 6, the weight losses were 6.4 and 4.4% in Plenity™ and control arms, respectively, and the responder rate at 5% weight loss in Plenity™ arm was 58.6%. The study did not meet the first co-primary effectiveness endpoint but met the second co-primary effectiveness endpoint. Most device-related AEs were of gastrointestinal origin (mainly abdominal distension, diarrhea, infrequent bowel movements, and flatulence, mild in the majority of cases), observed in 84 subjects (37.7%). No device-related SAEs were observed.

Overall, Plenity™ is safe and has a modest effectiveness. The device was cleared by the FDA in April 2019. It is indicated to aid in weight management in overweight and obesity with BMI between 25 and 40 kg/m^2, in conjunction with lifestyle recommendations. It is contraindicated in pregnancy, non-adult subjects, and history of allergic reaction to the components of Plenity™ capsule. No relevant complications have been reported.

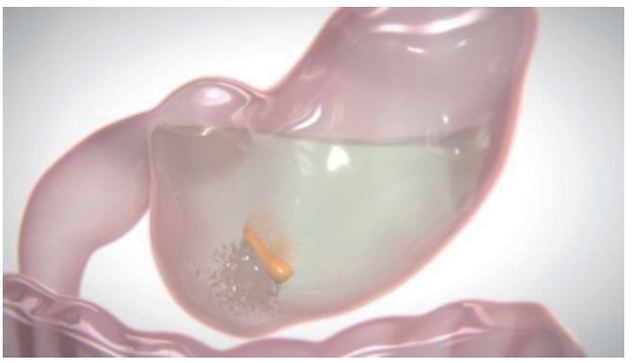

Figure 7.
Plenity™ (Gelesis, Inc.—Picture downloaded from the internet).

Comparative effectiveness of the above anti-obesity medical devices is reported in **Table 2**.

Medical device	Treatment duration	Total body weight loss
Lap-Band®	36 months	18.0%
AspireAssist®	12 months	12.1%
Orbera™ Intragastric Balloon System	6 months	10.2%
TransPyloric Shuttle	12 months	9.5%
Obalon Balloon System	6 months	6.6%
Plenity™	6 months	6.4%
SmartByte Device	4 months	1.7%

Table 2.
Approved/cleared anti-obesity medical devices in the USA ranked by extent of total body weight loss in pivotal studies.

Relevant complications (non-exhaustive list), some being very rare, of the above anti-obesity medical devices are reported in **Table 3**.

Medical device	Treatment duration	Relevant complication
Lap-Band®	36 months	Proximal gastric enlargement, band erosion or migration, system leaks
AspireAssist®	12 months	Skin irritation, infection, electrolyte abnormalities
Orbera™ Intragastric Balloon System	6 months	Balloon migration, intestinal obstruction, gastric ulcer, gastric perforation
TransPyloric Shuttle	12 months	Device impaction, gastric ulcer
Obalon Balloon System	6 months	Balloon migration, intestinal obstruction, gastric ulcer, gastric perforation
Plenity™	6 months	None
SmartByte Device	4 months	Choking on food, mouth soreness

Table 3.
Relevant complications of the approved/cleared anti-obesity medical devices in the USA in pivotal studies.

Cost of the above anti-obesity medical devices is reported in **Table 4**.

Medical device	Average cost (Range)
Lap-Band®	$15,000 ($10,000–$30,000)
AspireAssist®	$10,000 ($7,000–$13,000)
Orbera™ Intragastric Balloon System	$6,000 ($3,000–$9,000)
TransPyloric Shuttle	To be determined
Obalon Balloon System	$8,000 ($6,000–$9,000)
Plenity™	$100/month
SmartByte Device	$500

Table 4.
Cost of the approved/cleared anti-obesity medical devices in the USA.

8. Anti-obesity medical devices withdrawn from the market in the USA

Several anti-obesity medical devices have been withdrawn by the manufacturers from the market in the USA after approval by the FDA (e.g., Maestro Rechargeable System, Realize Adjustable Gastric Band, ReShape Integrated Dual Balloon System, Garren Gastric Bubble).

9. Anti-obesity medical devices under investigation or pending approval

Several anti-obesity medical devices are currently in development in different countries (e.g., Epitomee Device [18]).

EndoBarrier® has obtained a CE mark in the EU but its approval in the USA has been challenged for safety reasons [8, 11–14].

10. Over-the-counter anti-obesity medical devices

A variety of anti-obesity medical devices are available as over-the-counter products (e.g., NozNoz, slow control fork, slipper genie).

11. Conclusions

Anti-obesity medical devices represent a heterogenous family of devices in terms of presentation, usage/administration, mechanism of action, effectiveness, safety, regulation, availability, and cost. They offer an attractive approach in managing obesity. Anti-obesity medical devices are positioned to bridge the gap between more conservative treatments (e.g., lifestyle) and more aggressive interventions (e.g., bariatric surgery). Their use should always be combined with lifestyle changes.

Considering the large market size of obesity treatment and the small percentage of subjects treated with drugs or bariatric surgery, anti-obesity medical devices can play a major role in the management of obesity.

Conflict of interest

The author received honorarium for consultancy from Gelesis, Inc.

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