ATATÜRK ÜNİVERSİTESİ YAYINLARI
ATATURK UNIVERSITY PUBLICATIONS

Review *Derleme*

DOI: 10.61745/tss.1671486

The Importance of Nutrition Before and Following Metabolic/Bariatric Surgery

Metabolik/Bariatrik Cerrahi Öncesinde ve Sonrasında Beslenmenin Önemi

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ABSTRACT

Obesity is a chronic disease, a global epidemic and among the non-communicable disease targets which are identified by World Health Organization (WHO). Bariatric surgery (BS) is one of the treatment approaches used in the fight against obesity. In this article, it is aimed to present general information about BS, nutritional evaluation before and after BS, various nutrition-related conditions, and information on how food supplements and diet phases should be maintained. In addition, factors that should be taken into consideration in individuals undergoing BS and new approaches in BS are included. BS has different methods, such as restrictive and malabsorptive methods. The process before and after BS differs. It is important to evaluate and follow up on an individual basis in a multidisciplinary way. BS methods may have an effect on the absorption of nutrients and the food intake may not meet the requirement due to anatomical changes after surgery. Therefore, food supplements should be given based on the need. In addition, an individual's diet should progress in stages. Considering the risk factors of individuals with BS, postoperative body weight loss should be maintained in the healthiest way. In order to use BS as an effective tool in obesity management, it is considered necessary to develop solutions for the risk factors carried by the individuals who constitute the target group for BS, to manage and maintain the process and follow-up in the most ideal way.

Keywords: Bariatric surgery, obesity, food supplements, weight loss

ÖZ

Obezite, Dünya Sağlık Örgütü (DSÖ) tarafından tanımlanan bulaşıcı olmayan hastalık hedefleri arasında yer alan, kronik bir hastalık ve küresel bir salgındır. Bariatrik cerrahi (BC), obeziteyle mücadelede kullanılan tedavi yöntemlerinden biridir. Bu makalede, BC ile ilgili genel bilgiler sunulmasının yanı sıra, BC öncesi ve sonrası beslenme değerlendirmesi, beslenmeyle ilişkili çeşitli durumlar, gıda takviyeleri ve diyet evrelerinin nasıl sürdürülmesi gerektiği konularında bilgi verilmesi amaçlanmıştır. Ayrıca, BC geçiren bireylerde dikkate alınması gereken etkenler ve BC'deki yeni yaklaşımlar bu makalede ele alınmıştır. BC'nin kısıtlayıcı ve malabsorptif yöntemler gibi farklı yaklaşımları vardır. BC öncesi ve sonrası süreçler birbirinden farklılık gösterir. Bu süreçte, multidisipliner bir yaklaşımla bireysel bazda değerlendirme ve takip yapılması önemli görülmektedir. BC yöntemleri, besin ögelerinin emilimini etkileyebilir ve ameliyat sonrası meydana gelen anatomik değişiklikler nedeniyle besin alımı, vücudun ihtiyaçlarını karşılamayabilir. Bu yüzden, bireyin gereksinimlerine göre gıda takviyeleri verilmelidir. Ayrıca bireyin diyetinin aşamalar halinde ilerlemesi gerekmektedir. BC geçiren bireylerin risk etkenleri göz önünde bulundurulduğunda, ameliyat sonrası vücut ağırlığı kaybı en sağlıklı şekilde sürdürülebilmelidir. BC'nin, obezite yönetiminde etkili bir araç olarak kullanılabilmesi için BC'nin hedef grubunu oluşturan bireylerin taşıdığı risk etkenlerine yönelik çözümler geliştirilmesi, ameliyat öncesi, ameliyat sırası ve ameliyat sonrasındaki sürecin en ideal şekilde yönetilip sürdürülmesi gerektiği düşünülmektedir.

Anahtar Kelimeler: Bariatrik cerrahi, obezite, gıda takviyeleri, vücut ağırlığı kaybı

Received/ Geliş Tarihi 19.09.2024
Revision request/Revizyon Talebi 25.09.2024
Son Revizyon/Last Revision 05.03.2025
Accepted/Kabul Tarihi 17.03.2025
Publication Date/Yayın Tarihi 08.04.2025

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Cite this article: Bayar E, Besler HT. The Importance of Nutrition Before and Following Metabolic/Bariatric Surgery. *Trends Surg Sci*. 2025;4(1):51-64

INTRODUCTION

Obesity is a risk factor for diseases which are chronic and a threat at a global level. Also, obesity is amongst the global non-communicable targets of disease identified by World Health Organization (WHO). It is stated that in 2015, 107.7 million children and 603.7 million grown-ups across the world had obesity.[1] Also, according to the World Obesity Atlas (2024), the projected increase in the prevalence and number of overweight adults (BMI ≥25-30 kg/m^2) is 1.39 billion, 1.52 billion, 1.65 billion and 1.77 billion in 2020, 2025, 2030 and 2035, respectively. In addition, the number of adults with obesity (BMI ≥30 kg/m^2) is 0.81 billion, 1.01 billion, 1.25 billion, and 1.53 billion in 2020, 2025, 2030, and 2035, respectively. The proportion of adults worldwide who are overweight or obese is expected to increase from 42% in 2020 to 54% in 2035.[2] There are various treatment methods (diet intervention, exercise, surgery, etc.) for obesity, which is a chronic, multifactorial and complex disease. Bariatric surgery (BS), one of these methods, is a method used in cases of severe obesity, and various conditions must be met for its application.[3] BS was first reported by Edward Mason in the mid-1960s, and it was stated that body weight loss could be achieved through restrictive and malabsorptive methods. Gastric bypass (GB) was first applied, and in 2001, U.S. Food and Drug Administration (FDA) confirmed the usage of Laparoscopic Adjustable Gastric Band (LAGB) method in America. The mortality rate observed with BS in the late 1990s was known to be 0.5-1.0%. The safety of BS has improved in recent years.[4] Severe obesity causes comorbidities and mortality and it is stated that BS has a reducing effect on these factors by providing long-term body weight loss.[5] BS methods can be restrictive, malabsorptive, or it can be both restrictive and malabsorptive. In restrictive methods, there is no intervention towards the digestive system but the quantity of food which can be kept in the stomach is being reduced that it leads to restriction. Vertical banded gastroplasty (VBG), (Laparoscopic) sleeve gastrectomy (L)SG and (laparoscopic) adjustable gastric banding (L) AGB methods are one of the restrictive methods. For malabsorptive methods, there is intervention towards the digestive system and it leads to malabsorption. One of the malabsorptive methods which can be mentioned is biliopancreatic diversion (BPD). And some of the methods which are both restrictive and malabsorptive are Roux-en-Y gastric bypass (RYGB), mini gastric bypass (MGB), single anastomosis duodeno-ileal bypass (SADI), single anastomosis gastric-ileal bypass (SAGI) and biliopancreatic diversion with duodenal switch (BPD-DS).[6]

Metabolic and Bariatric Surgery

Metabolic and bariatric surgery (MBS) is considered for people with a BMI of ≥35 kg/m^2, with or without comorbidity, and in the presence of metabolic disease for people with a BMI of 30-34.9 kg/m^2. For Asians, it is considered appropriate to use different BMI values (BMI ≥27.5 kg/m^2 to apply MBS) as a basis and MBS for children and adolescents should be decided upon careful evaluation. Generally for children and adolescents with BMI >120% of the 95th percentile and a major status of comorbidity, or a BMI >140% of the 95th percentile is being used as a basis to consider applying MBS. There is no upper age limit for MBS application. For the evaluation of elderly individuals, it is seen appropriate that comorbidity status and factors related to frailty to be taken into consideration.[7]

BS methods are diverse and it causes differences in the functioning of the digestive system and affects hormone levels.[3] Some of the BS methods (e.g. gastric banding) are completely anatomical and do not affect metabolic pathways. Some other methods (e.g. Roux-en-Y gastric bypass) have an effect on the anatomy of the digestive system and change physiological parameters. Methods that affect physiological parameters reduce orexigenicity and cause an increase in the number of anorexigenic hormones. Thus, physical hunger is suppressed.[6,8] Peptide hormones such as ghrelin, leptin, adiponectin, neuropeptide Y are associated with appetite and energy consumption. Appetite is regulated by central and peripheral hormones and nerve signals, which affects the individual's response to food intake. Disruption in the balance of orexigenic and anorexigenic hormones is known to be one of the main pathophysiological causes of obesity.[9] In a meta-analysis study aiming to evaluate the alterations in gastrointestinal hormones and adipokines post-BS, it was concluded that there was a significative decrease in leptin, ghrelin, interleukin-6 (IL-6), tumor necrosis factor-α (TNF-α), C-reactive protein (CRP), and interleukin-1β (IL-1β) levels and a significative increase in adiponectin, peptide YY (PYY) and glucagon-like peptide-1 (GLP-1) levels.[10]

The process after BS varies depending on whether these methods affect the absorption of nutrients.[3] The estimated numbers of BS interventions from 2018 to 2022, as stated by American Society for Metabolic and Bariatric Surgery (ASMBS), are presented in Table 1[11] and some of the surgical procedures are given as Figure 1. Non-surgical procedures also include methods such as balloon, Primary Obesity Surgery Endoluminal (POSE), aspire assist and transpyloric shuttle.[1]

Table 1. Estimate of Bariatric Surgery Numbers. 2018-2022[11]

	2022	2021	2020	2019	2018
Sleeve	160.609	152.866	122.056	152.413	154.976
RYGB	62.097	56.527	41.280	45.744	42.945
Band	2.500	1.121	2.393	2.375	2.660
BPD-DS	6.096	5.525	3.555	2.272	2.123
Revision	30.894	31.021	22.022	42.881	38.971
SADI	1.567	1.025	488	-	-
OAGB	1.057	1.149	1.338	-	-
Other	6.189	7.339	1.221	6.060	5.847
ESG	4.600	2.220	1.500	-	-
Balloons	4.358	4.100	2.800	4.655	5.042
Total	**279.967**	**262.893**	**198.651**	**256.000**	**252.564**

RYGB: Roux-en-Y gastric bypass; BPD-DS: Biliopancreatic diversion with duodenal switch; SADI: Single anastomosis duodeno-ileal bypass; OAGB: One anastomosis gastric bypass; ESG: Endoscopic sleeve gastroplasty

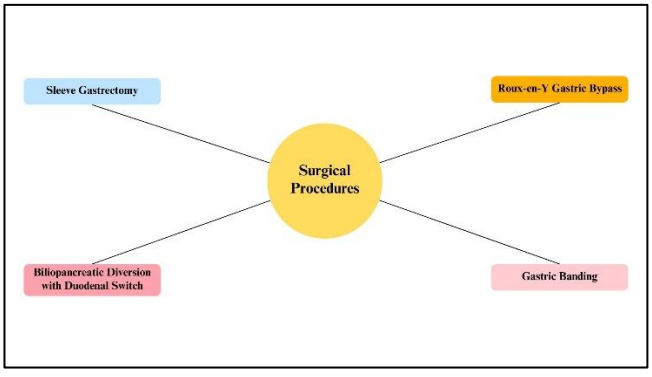

Figure 1. Surgical procedures of bariatric surgery[1]

Deficiency of some nutrients (e.g. vitamin B12, folic acid, iron) is observed after BS. It is also known that nutritional deficiencies (e.g. vitamin B12, vitamin D, folic acid, calcium, iron) are prevalent before BS. These deficiencies may be caused by absorption disorders, insufficient food intake or eating behaviors. Follow-up of patients is important in the process after BS.[3] Nutritional deficiencies after BS are due to various reasons. For example, decreased 25-hydroxyvitamin D concentrations following body weight loss are considered to be associated with increased retention and storage of vitamin D in adipose tissue. For vitamin B12, it is thought that one of the reasons may be the decrease in intrinsic factor production. For fat-soluble vitamins, it is thought that one of the reasons may be biliary pancreatic lesion that causes malabsorption of fat-soluble vitamins.[6] The impact of BS on nutritional status is mainly associated with a decrease in gastric volume and nutrient absorption.[5]

The nutrition therapy after BS should be progressed in stages, ensuring the individual's tolerance. At the same time, it should be ensured that nutritional requirements are met and digestive complications are minimized. It is important that nutritional treatment is specific to the individual and followed by a multidisciplinary team (medical specialist, BS expert dietitian, nurse, etc.). Regular follow-up should be done every 3 months for the first year post-BS, and one time in a year after the first year.[3] The most well-known BS methods include SG, RYGB, OAGB, AGB, and biliopancreatic diversion with or without duodenal switch (BPD/DS).[12]

Before Bariatric Surgery

Moderate body weight loss (about 5-10%) is recommended before BS to ease the surgery and decrease complications. For this purpose, individuals can be applied to a very low-calorie diet (600 kcal/day) or a low-calorie diet (800-1200 kcal/day). However, the situation which is catabolic and increase in oxidative stress that occur with very low-calorie diets should be taken into consideration, as they may have a negative impact on the surgery.[5] Checklist before the BS should include nutrition screening for iron, vitamin B12, folic acid and 25-vitamin D (vitamin A and vitamin E as optional). It shall be noted that in the case of malabsorptive procedures, more extensive screening is needed on the basis of indications and potential risks. Endocrine assessment (e.g. HbA1c, TSH), lifestyle evaluation (e.g. sleep quality, healthy eating, fitness), optimizing glycemic control are also included in the preprocedure checklist.[1] A calorie-restricted diet is recommended before BS to reduce perioperative complications associated with the surgery. There are contradictions regarding the effectiveness of these low-energy diets and body weight loss before the surgery on the BS process.[13] A systematic review and meta-analysis study aiming to evaluate the

Table 2. The suggested components of routine nutritional assessment and nutritional preparation process before the surgery[12]

Pre-surgery nutritional assessment	Pre-surgery nutritional preparation process
Weight-management history	Adjustment of the ideal eating and living behaviours
Eating patterns	Correcting of micronutrients deficiencies
Eating pathologies	Weight loss before the surgery
Anthropometric measurements	Progress in glycemic control for patients who have diabetes
Nutritional status	Initialisation of physical activity
Supplementation use	Building up the information on nutrition, obesity, and BS process
Skeletal status	Consultancy of nutrition
Dental hygiene	
Physical activity practices	
Bariatric surgery information	
Anticipations from the surgery	

effectiveness of body weight loss before BS concluded that body weight loss in the period before the surgery has moderate effects on the process for the perioperative period, but has no effect on long-term body weight loss.[14] However, due to the potential benefits of body weight loss in the preoperative period, it is recommended that people with a BMI over 50 kg/m^2, a large waist circumference, and a thick abdominal wall or intra-abdominal fat tissue follow a low-calorie diet. In the period which is before the operation, the target is generally to decrease the body weight by 10% or decrease 5% of excess body weight within 2 to 12 weeks before surgery. It should be taken into consideration that side reactions (e.g. gallstones, hair loss, lean mass loss, constipation) may occur if very low-calorie diets are applied in the preoperative period.[13]

Nutritional deficiencies of individuals before BS can be caused by a low-quality, high-calorie, high-fat diet that lacks nutritional diversity. At the same time, factors such as adipose tissue inflammation, increased adipose mass, and an increase in the signification of the systemic iron regulatory protein hepcidin due to obesity may cause nutritional deficiencies.[5] It is stated that the nutritional deficiencies seen in obese individuals before the BS intervention may be due not only to malabsorption and

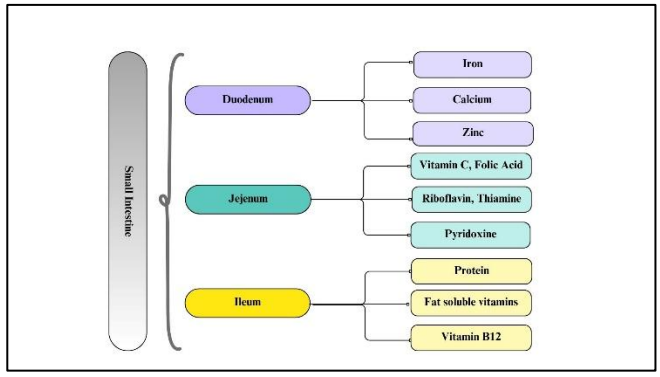

Figure 2. Absorption sites of some of the nutrients in the small bowel[18]

rapid body weight loss resulting from the surgery, but also to a malnutrition state that existed in the previous period. There may also be a decrease in the bioavailability of micronutrients in obese individuals. It is important to emphasize a healthy diet that includes all the elements.[15] Micronutrient deficiencies are frequently seen in patients before bariatric surgery. It is stated that two-thirds of patients have malnutrition before surgery. Since it is also a factor affecting the outcome of surgery, screening for malnutrition before surgery is recommended. Serum albumin and prealbumin levels are used to assess protein status in preoperative nutritional status, and low levels suggest malnutrition. It is thought that preoperative malnutrition detection accelerates recovery, reduces complications, and provides long-term health outcomes.[16] The suggested components of nutritional assessment and preparation process before BS are given as Table 2.[12]

After Bariatric Surgery

The physiological and anatomical change that the gastrointestinal system undergoes after BS may cause nutritional deficiencies. Nutritional deficiencies are related to many factors such as the surgical method applied, nutritional status before surgery, adherence to diet and food supplements given after surgery. Nutritional deficiencies are more common after malabsorptive methods compared to restrictive methods.[3] In a retrospective cohort study aimed at evaluating the occurrence status and conditions of nutritional deficiencies after BS in detail, the effect of SG, AGB and RYGB methods in the post-operative process was evaluated. As known, AGB is a restrictive method and there is no bypass of the gastrointestinal tract. Meanwhile, malabsorption is involved in the RYGB method, partial gastrectomy is performed in the SG method and hormonal changes are observed. In the study, it was concluded that RYGB and SG methods were associated with a 2.4 to 3.0 times probability of developing

Table 3. Mechanisms of nutritional deficiencies[3,19-23]

Nutrient	Reasons of deficiency	Prevalence of deficiency		Supplement Recommendations
		Pre-op	Post-op	
Iron	Low food intake Poor tolerance Malabsorption Decrease of hydrochloric acid secretion Intake of other supplements (such as calcium)	45% in patients with obesity	AGB 14% SG 18% RYGB 20–55% BPD 13–62% DS 8–50%	Required Minimum 18 mg/day (by multivitamin) (Grade C) 45-60 mg/day for menstruating patients (Grade C)
Vitamin B12	Decrease of the cobalamin stores The bypass of the surface which the vitamin is absorbed Low intake of food Low excretion of intrinsic factor Overgrowth of bacterial populations	2–18% in patients who have obesity 6–30% in patients taking proton pump inhibitors	RYGB 20% SG 4–20%	Required Orally: 350-500 µg/day As nasal spray: guided by the manufacturer Parenteral: 1000 µg/month
Folate/Folic acid	Low food intake Inadequate adherence to supplementation	54% in patients with obesity	Up to 65%	Required Orally: 400-800 µg/day (from multivitamin) (Grade B) 800-1000 µg/day for women of childbearing age (Grade B)
Calcium	Low food intake Inadequate adherence to supplementation Deficiency of Vitamin D Therapy for long-term proton-pump inhibitor The bypass of the surface which the vitamin is absorbed	66.7% in patients who are under 50 years of age and have raised values of carboxy-terminal telopeptide	RYGB 1.9% SG 9.3% BPD-DS 10%	Required BPD/DS: 1800–2400 mg/day LAGB, SG, RYGB: 1200–1500 mg/day
Vitamin D	Bile salt deficiency (which might occur with malabsorption) Overgrowth of bacterial populations Delayed blend of vitamin D	90% in patients with obesity	Up to 100%	Vitamin D3 dose: 3000 IU/day (Until blood levels of 25(OH)D are greater than the adequate level)
Vitamin B1 (Thiamine)	Low food intake The limited body stores of thiamine Persistent vomiting	29%	<1% to 49% (varies by surgery method and duration)	Required Minimum 12 mg/day (Grade C) 50 mg, once or twice in a day (Grade D)
Vitamins which are soluble in fat (Vitamin A, D, E and K)	Malabsorption	Vitamin A 14%, Vitamin E 2.2%	Vitamin A, up to 70% with RYGB and BPD/DS in 4 years. Deficiency of vitamin E and K are not common	Required Minimum 12 mg/day (Grade C) 50 mg, once or twice in a day (Grade D)

Table 3. (Continued) Mechanisms of nutritional deficiencies[3,19-23]

Zinc	Inadequate dietary intake Damage of intestinal mucosa Bypass of absorption sites	24-28% in general 74% of patients seeking BPD/DS	Up to 70% (RYGB %40 19% SG 34% AGB)	Required BPD/DS: 16–22 mg/day RYGB: 8–22 mg/day SG/LAGB: 8–11 mg/day
Copper	Inadequate dietary intake Reduced absorption due to BS procedures	70% in pre-BPD women	90% of patients RYGB 10–20%	Required BPD/DS or RYGB: 2 mg/day SG or LAGB: 1 mg/day (Copper to Zinc: 1/8-15 mg)

Grade A: Strong, Grade B: Intermediate, Grade C: Weak, Grade D: No evidence

Table 4. Prevention and treatment of prevalent gastrointestinal symptoms after bariatric surgery[27]

Symptom	Prevention and Treatment of the Symptom (Nutritional Therapies)
Dumping syndrome	Stay away from simple sugars Stay away from foods which have high glycemic index Bring together complex carbohydrates with protein and fiber in meals Keep liquids separated from solid foods
Diarrhea	Decrease fat consumption Ensure sufficient fluid intake
Constipation	Raise liquid consumption Raise consumption of foods which are rich in fiber Stay away from carbonated and sugar-sweetened beverages
Dysphagia	Eat slowly Stay away from hard and dry foods Do not continue eating in the case of dysphagia
Vomiting	Take small bites, eat slowly Keep liquids separated from solid foods Reintroduce the foods which have been associated with vomiting
Dehydration	Raise fluid intake

3 year post-operative nutritional deficiency when compared to AGB. The result of this study supports that nutritional deficiencies are observed less in restrictive methods.[17] It is known that different parts of the small bowel are responsible from the absorption of different nutrients. Therefore, nutritional deficiencies vary depending on the BS method applied. The absorption sites of nutrients in the small bowel are given as Figure 2. Decreased calorie intake is inevitable after BS, and one of the main nutritional deficiencies is protein malabsorption. Protein malabsorption is also caused by other factors related to food intake (e.g. poor intake, vomiting). Such factors might cause protein malabsorption which is characterized by low albumin levels, oedema and hearing loss.[18] Reasons and prevalence (pre-op and post-op) of some of the nutritional deficiencies and supplementation recommendations are given as Table 3.[3,19-23]

It is known that some groups are at greater risk in terms of nutritional status after BS. Patients with extreme BMI (BMI ≥50 kg/m^2), sarcopenic obesity, multiple deficiencies nutritionally, poor glycemic control, poor dental hygiene, impaired eating behaviors can be given as examples of this situation.[24] Other factors associated with postoperative risk can be mentioned as insulin resistance and diabetes, tobacco addiction, cardiovascular diseases, obstructive sleep apnea syndrome, functional disability, and hypoalbuminemia. Routine evaluation of individuals before surgery, determination of risk/benefit status and management of comorbidities are considered necessary to decrease the risk in the period post-surgery.[25] Protein-energy malnutrition and micronutrient deficiencies may occur after BS. It is known that individuals who do not comply with recommended dietary requirements are at risk of developing malnutrition. Protein malnutrition may occur especially after malabsorptive surgery methods. Individuals should be followed up for life to prevent malnutrition after BS.[26] Postoperative protein intolerance also affects bile and pancreatic enzyme secretion. Consumption of protein-rich foods may cause vomiting and gastrointestinal disorders.[16] Reactive hypoglycemia and dumping syndrome may occur after BS as well. For this situation, it is recommended to avoid quickly absorbed carbohydrates and alcoholic beverages and consume foods rich in fiber and protein.[5] Some gastrointestinal symptoms are frequently observed after BS. These symptoms and methods to prevent and treat the symptoms are given as Table 4.[27]

It is known that the change in the anatomy of the gastrointestinal system after BS affects hypothalamic

signaling and gut hormones. In addition, it is stated that BS increases satiety, affects food preferences, and causes differences in approaches regarding to tastes (such as a decrease in hedonic evaluation of sweet and fatty foods).[5] It is known that following some BS methods, an increase in satiety hormones (e.g. oxyntomodulin (OXM), glucagon-like peptide-1 (GLP-1), peptide YY (PYY)) is observed. This situation may constitute one of the main mechanisms for decreased hunger and increased satiety after surgery. In addition, it is suggested that the influence of the GLP-1 hormone on the increase in insulin excretion may be a factor. It is also thought that gut hormones can be used as a marker to reveal insufficient body weight loss post-surgery.[28] It is reported that there are alterations in taste perception and food preferences after BS. In a systematic review and meta-analysis study aiming to assess this situation, it was stated that the results were inconsistent. However, the change in the expression of sweet taste and amino acid receptors is seen mostly in the intestinal segments, while the change for fatty acid receptors is seen mostly in the colon.[29] In a cross-sectional study aiming to describe the change in individuals' food preferences after BS, it was concluded that individuals' preferences depend on factors such as sensory perceptions, follow-up time and the success level of the surgery. It was stated that there was a change in preference among individuals towards healthier food options.[30] It is known that patients constitute a risk group for eating disorders in the post-BS period. In a systematic review and meta-analysis study aiming to evaluate the relation between recurrence of eating disorders and BS, it was concluded that the prevalence of eating disorders after surgery was 7.83%.[31] It is known that eating disorders are seen at higher rates in BS candidates compared to the general population. At the same time, BS candidates' perception of shape and body weight is more dominant. This is one of the reasons that makes BS candidates a risk group in the period after the operation. It is also thought that problematic eating behaviors may be associated with body weight regain after BS.[32]

Diet Stages and Dietary Supplements After Bariatric Surgery

Rapid body weight loss after BS may cause unintentional loss of fat-free mass and muscle mass. In this process, adequate intake of protein (minimum 60 g/day or up to 1.5-2.1 g/ideal body weight (kg)/day based on individual) is considered as protective against lean body mass loss. In order to meet this protein requirement, liquid protein supplements (30 g/day) are recommended in the first months.[5] The protein source is also considered as important. For the maintenance of lean tissue, it is suggested to consume foods with high leucine content (soy products, eggs, meat, legumes). Products with high whey protein content also increase leucine intake and can be considered as a good option.[27] Due to its branched-chain amino acid content, whey protein is among the protein supplements frequently used after BS.[13] Since there are individual differences in the absorption of nutrients, food supplements should be specific to the individual and the individual's periodic laboratory routine shall be observed.[5] The continuation of multivitamin and mineral supplements should be decided based on the calorie intake level and degree of malabsorption. In cases of increased parathyroid hormone levels, decreased calcinuria and/or insufficient oral intake, calcium supplementation should be associated with vitamin D intake.[33] The dosage of calcium supplements should be divided. It is recommended to take calcium carbonate with a meal, meanwhile, there is no such condition for calcium citrate. For pregnant women, supplementation of vitamin A and K after BS are especially seen as important.[19] Similarly, in case of zinc deficiency, zinc supplementation should be associated with copper intake. Zinc supplementation should not exceed 30 mg per day and its interaction with other nutrients (folate, calcium iron, etc.) should be taken into consideration. It is known that deficiencies (although rare) in fat-soluble vitamins may occur in case of malabsorption or after long afferent loop surgery. In case of deficiency, supplementation should be considered.[33] After BS, it becomes very difficult for patients to consume solid foods due to small stomach volume and gastric oedema. Therefore, dietary intervention is based on gradual progression of the diet, starting with a liquid or very soft diet to consume solid and chewable foods within 2-4 weeks.[5] In the first weeks, intake of calorie is quite limited due to anatomical changes. It is important to complete protein intake during this period.[13] Ideal eating behaviors after BS include having 4-6 meals during the day (dividing the intake of food), consuming foods which have high protein content, chewing foods in a slow manner, finishing eating when feeling saturated, staying away from the consumption of beverages which are carbonated and calorie rich, increasing consumption of water, consuming solid and liquid foods at separate times, avoiding snacking and such.[12] Stages of diet after RYGB, LSG, LAGB and BPD/DS are given as Table 5.[13] The recommendations related to nutritional assessment before the surgery, biochemical monitoring and food supplementation after the surgery and some other recommendations related to vulnerable groups and clinical problems are given as Table 6.[34]

Table 5. Stages of diet after RYGB, LSG, LAGB, BPD/DS[13]

	Time for Beginning	Food	Key Points	Avoided/Limited/Moderated Foods	Calorie and Macronutrient Requirements
Stage 1	Right after surgery	Clear liquids (liquids with no calories) Ice chips	Fluid intake shall begin after swallow test (in case there is an issue, sipping the water is appropriate). 15 ml of liquid every 30 minute (in the first 2 hours), raise it by 15 ml every 15 minute for the rest of the day	Beverages which are carbonated, have caffeine or sugar (avoided). Using straw is limited.	**Calorie:** Post-bariatric caloric needs are up to three factors; age, sex and activity level. Negative balance in energy is needed. 400-500 calorie in first days, gradually increase it up to 900 calories in 6 months. Calorie intake shall not be over 1000 calorie in the first year of surgery. **Carbohydrates:** %35-50 of daily calorie intake. Complex or high-fiber carbohydrates are recommended. 100-130 g/day is required.
Stage 2	2nd-3rd days	Water Watered fruit juice (sugar-free) Broth Jelly (sugar-free)	30 ml liquids every 15 minutes (no beverage which are carbonated and no sugar). Liquids shall be sipped slowly. Fruit juice (dilute with water; half and half). Total fluid intake: 1500-1800 ml/day.	Caffeine is limited. Using straw is limited.	
	4th and 10-14th days	Low/skim milk Plain yoghurt Protein powder Protein shakes Watered fruit or vegetable juice Broth Jelly (sugar-free) Smooth vegetable soup	120-170 ml liquids every hour. 25-30 g protein/serving (100–200 calories; <10 g sugar; <15 g carbohydrates). Total fluid intake: 1500-1800 ml/day. Minimum 4 cups of water each day.	Plain yoghurt which contains added sugar over 25 g is limited. Salty liquids in moderation. Beverages which are carbonated, with caffeine or sugar (avoided). Using straw is limited.	
Stage 3	10-14th days and end of 3rd week	Low-fat meat (ground, pureed). Eggs. Low-fat cheese. Soups (strained). Well-cooked vegetables Fruits (non-fibrous, pureed).	3-5 small meals (when patient can tolerate 1/2 cup of food at a time, 3 small meals and 2 snacks should constitute the daily intake). Focus on protein-rich foods. Drink water 15 minute before or 30 minute after a meal). Continue protein powders.	Not drinking the water with or right after a meal	**Protein:** 60–160 g/day after RYGB and 60–80 g/day or 1.1 g/ideal body weight (kg)/day after SG. Daily consumption can be up to 2.1 g/kg/day (based on ideal body weight of individiual).
Stage 4	≥4th week	Advanced diet	Minimum 1500-1800 ml liquids (well hydration is important).	Not drinking the water with or right after a meal.	

		(according to individual's tolerance)	Introduce new foods one by one. Drink water 15 minute before or 30 minute after a meal. Include raw fruits and vegetables based on toleration of the individual. Intake of food shall increase step by step (based on suggested daily intake of calorie). Every meal shall last 20 minutes. Foods shall be chewed slowly and adequately	Consumption of bread, rice and pasta is restricted (until making sure that foods which are rich from protein are tolerated well).	**Fat:** Generally %35-42 of daily calorie intake is reported.

RYGB: Roux-en-Y gastric bypass, LSG: Laparoscopic sleeve gastrectomy, LAGB: Laparoscopic adjustable gastric banding, BPD/DS: Biliopancreatic diversion with duodenal switch

Table 6. Recommendations related to the process before and after the surgery[34]

	Preoperative nutritional assessment	Postoperative care and biochemical monitoring	Postoperative vitamin and mineral supplementation	Abnormal test results, clinical problems, pregnancy and adolescents
Grade A	N/A	N/A	N/A	N/A
Grade B	Full blood count control (e.g. haemoglobin, vitamin B12 levels). Control of serum 25-hydroxyvitamin D levels. Control of serum/plasma parathyroid hormone levels.	Control of full blood count and serum ferritin levels. Control of serum folate, 25-hydroxyvitamin D, vitamin A, vitamin E, vitamin K1, PIVKA-II, serum/plasma zinc and vitamin B12 levels.	Using iron and selenium supplement after SG, RYGB and malabsorptive procedures. Supplement of ferrous sulphate (200 mg/day), ferrous fumarate (210 mg/day), ferrous gluconate (300 mg/day) (consider it as twice in a day in menstruating women, adjust it according to the blood results). Routine supplementation of vitamin B12 with intramuscular vitamin B12 injections after malabsorptive procedures or SG, RYGB. Daily supplementation of vitamin A after malabsorptive procedures. Multivitamin and mineral supplementation (containing dietary reference intake of zinc and thiamine).	N/A
Grade C	N/A	Control of serum selenium and copper levels	Vitamin A supplementation, especially in the case of people having deficiency symptoms. Daily supplementation of vitamin E and vitamin K after malabsorptive procedures. Supplementation of 30 mg/day zinc after malabsorptive procedures.	N/A

Table 6. (Continued) Recommendations related to the process before and after the surgery[34]

	Preoperative nutritional assessment	Postoperative care and biochemical monitoring	Postoperative vitamin and mineral supplementation	Abnormal test results, clinical problems, pregnancy and adolescents
Grade D	Comprehensive assessment nutritionally before BS. Control of serum calcium levels. Control of serum thiamine levels.	Dietetic support. Follow-up (minimum two years). Monitoring the nutritional status (at least once in a year). Control of vitamin A levels in the case of steatorrhoea or signs of vitamin A deficiency. Control of serum vitamin E levels in the case of uncomprehended anaemia or neuropathy. Control of serum selenium levels in the case of diarrhoea, metabolic bone disease, uncomprehended anaemia or uncomprehended cardiomyopathy and at regular intervals.	Folic acid supplement (400-800 µg/day). Supplementation of vitamin D3 (2000-4000 IU/day after SG, RYGB, malabsorptive procedures). Using fat soluble vitamins which are miscible in water post-malabsorptive procedures as a way to improve absorption. Supplement (containing 2 mg copper) after RYGB, SG, BPD/DS. Recommendation of multivitamin and mineral supplement (which contains selenium). Oral thiamine supplementation (200-300 mg/day) in the case of poor dietary intake, dysphagia, vomiting or fast weight loss.	Considering the causes of blood loss in the case of iron deficiency anemia. Treating iron, vitamin B12 and folic acid deficiency according to NICE, CKS (National Institute for Health and Care Excellence, Clinical Knowledge Summaries) Anaemia. Applying hydroxocobalamin (1 mg/alternate days, intramuscularly) in the case of neurological involvement through vitamin B12 deficiency, consider it as in every 2 months after having no further improvement). Administering hydroxocobalamin (1 mg/three times a week for 2 weeks intramuscularly) in the case of no neurological involvement. During the treatment of vitamin B12 deficiency, maintain it as 1 mg/2-3 months lifelong (intramuscular). Folic acid supplement (5 mg/day) at least for 4 months. Treatment of vitamin A deficiency (10.000-25.000 IU/day/1-2 weeks, also checking vitamin A levels at 3 months). Oral vitamin E supplementation (100-400 IU/day) (checking at 3 months). Doing the adjustments according to serum lipids while considering the vitamin E nutritional status). Checking both zinc and copper levels while assessing replacement of one of it. Zinc/copper ratio shall be 8-15/1 mg (monitoring is important as the absorption of each mineral is linked to each other). In the case of prolonged vomiting or dysphagia, consider the risk of thiamine deficiency and plan the treatment according to that. Avoiding pregnancy following the first 12-18 months of surgery. Women (BMI <29.9 kgm^2 and planning pregnancy) taking 400 µg/day folic acid till the 12th week of pregnancy. Women (who have type 2 diabetes, BMI >30kgm^2) taking 5 mg folic acid until the 12th week of pregnancy. Nutritional screening of each trimester during pregnancy for women who had BS.

Table 6. (Continued) Recommendations related to the process before and after the surgery[34]

	Preoperative nutritional assessment	Postoperative care and biochemical monitoring	Postoperative vitamin and mineral supplementation	Abnormal test results, clinical problems, pregnancy and adolescents
GPP	Seek advise in the case of possibility of hyperparathyroidism. Control of serum vitamin A, zinc, copper and selenium levels in the case of going through malabsorptive methods of surgery. Control of serum magnesium levels. Routine control of HbA1c, lipid profile, liver and kidney functions. Treatment and correction of nutritional deficiencies.	Monitoring renal and liver functions. Monitoring full blood count and serum folate, calcium, vitamin D, vitamin E, serum/plasma zinc, copper, selenium and ferritin levels. Considering ≥75nmol/L of serum 25-hydroxyvitamin D levels as sufficient. Measuring total 25-hydroxyvitamin D in the case of vitamin D2 supplements. Control of parathyroid hormone in case it is not done before BS. Control of serum/plasma zinc levels in the case of uncomprehended anaemia, hair loss or alterations in taste acuity. Monitoring serum copper levels in the case of zinc supplementation and uncomprehended anaemia or poor wound healing. Considering the treatment of thiamine deficiency in the case of rapid weight loss, vomiting, alcohol abuse, poor dietary intake, oedema or signs of neuropathy. Monitoring HbA1c in the case of diabetes and monitoring lipids in the case of dyslipidaemia.	Reviewing and adjusting vitamin and mineral supplements. Using a complete multivitamin and mineral supplement after all surgical procedures. Recommending a supplement which contains iron (particularly to adolescents). Taking iron supplements with citrus fruits/drinks or vitamin C. Recommending people to take calcium and iron as having 2 hour apart between. Recommend vitamin B12 injections (see grade b) to be done in every 3 months. Ensuring good dietary calcium intake in the case of requirement to be higher. In the case of PTH to raise, while serum calcium and 25-hydroxyvitamin D levels are normal, think about recommending a combined supplementation which contains both vitamin D and calcium. Recommend calcium supplement to be taken in divided doses (calcium carbonate with food and calcium citrate with or without food, calcium citrate is preferred in the case of having kidney stones risk). Oral vitamin A supplementation (as 3000 µg/day and adjust it). Oral vitamin E supplementation (as 100 IU/day and adjust it). Oral vitamin K supplementation (as 300 µg/day) after malabsorptive procedures. Intake of 15 mg/day zinc through the supplement. Recommending oral thiamine 3-4 months post surgery. Clinicians to realize thiamine deficiency and	Considering the potential causes of protein malnutrition, protein energy malnutrition oedema symptoms. Considering protein, zinc, copper and selenium deficiency in the case of uncomprehended causes of anaemia or fatigue. Considering high dose vitamin D injections in the case of severe vitamin D deficiency (medical history of the patient is important). Considering vitamin A injections in the case of oral supplementations not responding to the treatment. 1-2 mg/day oral vitamin K supplement in the case of deficiency and checking the levels at 3 months. Zinc supplementation (high dose) for 3 months in the case of severe zinc deficiency and normal or borderline copper levels (rechecking the status also should be done). Referring to the reference levels specialized for pregnancy.

			people to look for advice in the case of poor dietary intake or prolonged vomiting.	

Grade A: Directly practicable to the target population, consistent overall (based on high quality and well conducted studies)
Grade B: Directly practicable to the target population, consistent overall or educed evidence (based on well conducted studies, not included the high quality meta-analyses)
Grade C: Directly practicable to the target population, consistent overall (based on well conducted case-control or cohort studies)
N/A: Not applicable
Grade D: Educed evidence (based on high quality systematic reviews and well conducted case-control or cohort studies) or based on non-analytical studies, expert opinion
GPP: Good Practice Point (based on clinical experience)

Regain of Body Weight After Bariatric Surgery

Successful loss of body weight after BS is identified as the loss of over 50% of excess body weight. After BS, 20-25% of patients experience body weight regain (progressive regain following successful loss of body weight) and insufficient loss of body weight (excessive body weight loss to be <50% within 18 months after BS) which might lead to revision of BS.[35] There are various definitions of postoperative body weight regain. These definitions may be based on the loss of excess body weight, the calculation of the nadir body weight, as well as the preoperative body weight. For example, regain of ≥10% or >15% of the nadir body weight can refer to weight regain.[36] After BS, body weight loss occurs very rapidly, especially in the first months. Loss of lean mass after BS leads to a decrease in energy expenditure and a tendency for the individual to regain body weight. The change in hormone levels after BS also causes regain of body weight.[3] Mechanisms related to hormones (increase in ghrelin, decrease in peptide YY and GLP-1 etc.), non-compliance with the diet (increase in caloric intake with time, grazing, not being followed up nutritionally), not being physically active enough, factors related to mental health (depression, control loss over eating) or surgery (enlargement of gastric pouch, stoma dilatation, or gastrogastric fistula) may cause body weight regain after BS. Body weight regain after various surgeries is as stated: 38% after LAGB, 27.8% after LSG, 3.9% after RYGB. In addition, insufficient body weight loss is 32-40% after LSG and 20% after RYGB, OAGB and LSG.[35] It is suggested that taste perception, appetite, food preferences and eating behaviors after BS are also related to postoperative body weight regain. Following some BS methods, individuals are reported to have decreased appetite and less desire for sweet foods. However, it is stated that this situation may not be long-lasting and cause body weight regain in that case.[37]

New Perspectives in Bariatric Surgery

There are approaches within the scope of future trends in the study field of BS. One of these approaches is robotic surgery. It is suggested that bariatric robotic surgery can be benefited from in individuals with high BMI, who have had previous gastrointestinal surgeries, or who will undergo revisional BS. It is thought that bariatric robot surgery, which has emerged as an innovative technique among body weight loss methods, may be a helpful factor in carrying out the process in a safer and least invasive manner.[38] The artificial intelligence can also be used in the field of BS. It is thought that it may be useful to develop algorithms that will identify the risk of postoperative complications or insufficient body weight loss specific to the individual. The use of validated algorithms may be among the future trends.[39] Another topic among future trends is the relationship between microbiota and BS. As the role of microbiota in the obesity pathogenesis is known, it is thought that gut microbiota changes based on the BS procedure.[40] After BS, changes in the bacterial population (such as an increase in the level of Escherichia coli) are observed. In addition, active compounds produced by the microbiota, (e.g. bile acids, short chain fatty acids) are known to have an influence on appetite and energy metabolism. It is thought that determining the state of microbiota before and after surgery may be an efficient factor on the security and success of BS procedures in long-term.[41]

CONCLUSIONS

Obesity is a chronic and multifactorial disease. It is also one of the factors that threaten health worldwide. BS, which constitutes the surgical intervention methods in the obesity treatment, is applied according to the degree of obesity and the accompanying comorbidity. There are different approaches for individuals who are considered vulnerable in terms of BS (adolescents, pregnant women, etc.). Individuals who constitute the target group of BS are also a group that needs to be taken into consideration due to their potential to exhibit risky behavior in terms of eating and food perception. It is considered necessary to evaluate the situation before BS in terms of nutrition-related factors to facilitate the process after BS. The effect of BS on the body (absorption of nutrients, hormones, etc.) varies depending

on the BS method applied. Considering this situation, after BS, the individual's diet should be progressed in stages as tolerated and nutritional requirements should be supplemented as needed. Body weight regain may be possible after BS. This situation suggests the necessity of taking some precautions and developing solutions regarding risk factors for the extent and sustainability of success in BS. Using innovative approaches is also among the future trends. It is considered important to develop guidelines regarding BS in the context of nutrition and dietetics, to conduct more comprehensive and long-term studies, and to define risk factors in more detail.

Hakem Değerlendirmesi: Dış bağımsız.
Yazar Katkıları: Fikir-EB, HTB; Tasarım- EB, HTB; Denetleme- EB, HTB; Kaynaklar- EB, HTB; Veri Toplanması ve/veya İşlemesi- EB, HTB; Analiz ve/ veya Yorum- EB, HTB; Literatür Taraması- EB, HTB; Yazıyı Yazan- EB, HTB; Eleştirel İnceleme- EB, HTB.
Çıkar Çatışması: Yazarlar, çıkar çatışması olmadığını beyan etmiştir.
Finansal Destek: Yazarlar, bu çalışma için finansal destek almadığını beyan etmiştir.

Peer-review: Externally peer-reviewed.
Author Contributions: Concept - EB, HTB; Design- EB, HTB; Supervision- EB, HTB; Resources- EB, HTB; Data Collection and/or Processing- EB, HTB; Analysis and/or Interpretation- EB, HTB; Literature Search- EB, HTB; Writing Manuscript- EB, HTB; Critical Review- EB, HTB.
Conflict of Interest: The authors have no conflicts of interest to declare.
Financial Disclosure: The authors declared that this study has received no financial support.

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