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Research Article

The temporal changes in mean platelet volume after bariatric surgery

Bariatrik cerrahi sonrası ortalama trombosit hacmindeki zamansal değişiklikler

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Abstract

Aim: Studies on obese individuals have proposed a correlation between weight loss and variations in mean platelet volume (MPV). Therefore, this study aimed to examine the changes in MPV in morbidly obese patients who underwent weight loss via bariatric surgery.

Material and Methods: A total of 328 morbidly obese patients who underwent sleeve gastrectomy (morbidly obese group) and were retrospectively evaluated from January 2010 to November 2014. The control group consisted of 53 non-obese patients who had laparoscopic cholecystectomy. Body mass index values and MPV values at preoperative (baseline), postoperative 1st month, 3rd month, and 12th month for both groups were documented.

Results: The baseline MPV values were comparable between morbidly obese group and control group (8.8 ± 1.8 vs. 8.6 ± 1.2, p = 0.283). In control group, there was no significant change in MPV levels during the 12-month follow-up. In morbidly obese group, mean MPV levels at the 1st and 3rd months post-surgery were similar, showing an increase compared to baseline levels. By the 12th month, mean MPV levels tended to decrease, becoming comparable to baseline values.

Conclusion: MPV levels increased in the early postoperative period following sleeve gastrectomy, they returned to baseline by the 12th month. These findings suggest that weight loss from bariatric surgery may influence MPV levels, but this effect normalizes over time.

Keywords: bariatric surgery, sleeve gastrectomy, mean platelet volume, obesit

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Öz

Amaç: Obez bireyler üzerinde yapılan çalışmalar, kilo kaybı ile ortalama trombosit hacmi (MPV) değişiklikleri arasında bir ilişki olduğunu öne sürmüştür. Bu nedenle, bu çalışma, bariatrik cerrahi ile kilo kaybı yaşayan morbid obez hastalarda MPV'deki değişiklikleri incelemeyi amaçladı.

Gereç ve Yöntemler: Ocak 2010 ile Kasım 2014 tarihleri arasında sleeve gastrektomi yapılan toplam 328 morbid obez hasta (morbid obez grup) retrospektif olarak değerlendirildi. Kontrol grubu, laparoskopik kolesistektomi geçiren 53 obez olmayan hastadan oluştu. Her iki grup için preoperative (bazal), postoperatif 1. ay, 3. ay ve 12. ayda vücut kitle indeksi ve MPV değerleri kaydedildi.

Bulgular: Bazal MPV değerleri, morbid obez grubu ile kontrol grubu arasında benzerdi (8.8 ± 1.8 vs. 8.6 ± 1.2, p = 0.283). Kontrol grubunda, 12 aylık takip süresince MPV seviyelerinde anlamlı bir değişiklik gözlenmedi. Morbid obez grubunda, cerrahi sonrası 1. ve 3. ayda ortalama MPV seviyeleri benzer olup, bazal seviyelere göre artış gösterdi. 12. ayda ise ortalama MPV seviyeleri azalma eğilimi göstererek, bazal değerlere benzer hale geldi.

Sonuçlar: MPV seviyeleri, sleeve gastrektomi sonrası erken postoperatif dönemde artış gösterdi, ancak 12. ayda başlangıç seviyelerine döndü. Bu bulgular, bariatrik cerrahi ile kilo kaybının MPV seviyelerini etkileyebileceğini, ancak bu etkinin zamanla normale döndüğünü göstermektedir.

Anahtar Kelimeler: bariatrik cerrahi, sleeve gastrektomi, ortalama trombosit hacmi, obezite

Introduction

Platelets are circulating, disc-shaped anucleate particles measuring 1-2 µm in size, derived from megakaryocytes with a lifespan of 8-10 days. The main role of plateletes is to maintain the integrity of blood vessels through adequate hemostasis and thrombosis [1]. The size and hemostatic potential of circulating platelets are different. When activated, platelets undergo a disc-to-sphere transformation, and reticulated platelets—larger and younger—emerge, leading to an increase in platelet size [2]. These younger larger platelets are metabolically and enzymatically more active and have greater prothrombotic potential than smaller platelets [3]. Platelets with large volume, containe more granules and produce greater amounts of vasoactive and prothrombotic factors such as thromboxane A2, platelet factor 4, beta-thromboglobulin, and serotonin [4].

Platelet size, measured as mean platelet volume (MPV), is a marker of platelet function and is positively associated with indicators of platelet reactivity [5]. In addition to increased MPV, the proportion of reticulated platelets has also been suggested as a marker of increased platelet turnover [6]. An increased in the MPV level is related to hyperaggregability and a shortened time of coagulation [7]. Elevated MPV plays a pivotal role in the pathogenesis of atherothrombosis and cardiovascular outcomes [8].

Obese patients often have elevated MPV levels, making them a risk group for thrombosis [9-12]. There are also studies that suggest either no relationship or a negative correlation between BMI and MPV levels [13-16]. Likewise, conflicting results have been reported in the few studies examining the impact of bariatric surgery on MPV levels, with some studies showing an increase, others showing a decrease, or no change in MPV post-surgery [17, 18]. Therefore, this study aimed to examine the changes in MPV in morbidly obese patients who underwent weight loss via bariatric surgery, addressing the gap in the literature on the impact of weight reduction on platelet function and the inconsistent findings in previous research.

Material and Methods

Patients who underwent bariatric surgery at the Fatih Sultan Mehmet Training and Research Hospital General Surgery Clinic between January 2010 and January 2014 were retrospectively enrolled in this study. The study received the Fatih Sultan Mehmet Training and Research Hospital Clinical Research Ethics Committee approval (Date: 27.10.2014, Decision No: 2014/9) and was conducted in compliance with the relevant ethical guidelines and the Declaration of Helsinki (2013 Brazil revision). The local ethics committee waived the requirement of informed consent due to the retrospective nature of the research.

Study population

A total of 328 morbidly obese patients who underwent sleeve gastrectomy (morbidly obese group) during the study period were retrospectively evaluated. Additionally, 53 non-obese

without any comorbidities who underwent laparoscopic cholecystectomy were included as a control group. All patients met the indications for bariatric surgery according to the 2006 guidelines of the International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) [19]. The inclusion criteria for the study were patients aged 18-60 years, with a BMI ≥ 40 kg/m^2 or a BMI of 35-40 kg/m^2 with comorbidities (such as metabolic diseases, cardiovascular diseases, respiratory diseases, joint diseases, psychological problems related to obesity), for whom weight loss achieved through surgical methods was expected to have a positive impact on these issues. Patients with a history of kidney disease, thyroid disease, chronic infectious disease, malignancy or renal or hepatic dysfunction, women who were pregnant, those using steroids or other immunosuppressive therapies, those with a BMI less than 35 kg/m^2, those with documented surgical histories, those who encountered postoperative complications, those who missed their postoperative follow-ups, and those with missing data were excluded from the study. No patients underwent any other bariatric surgery during the follow-up.

Study protocol

The hospital's electronic information system and patient files were used to gather demographic and clinical data. For the obese group, clinical parameters at preoperative (baseline), postoperative 1st month, 3rd month, and 12th month for both groups were documented, while for the control group, they were evaluated at baseline and postoperative 12th month. All samples were analyzed in a single laboratory using the same methodology as described below.

Laboratory parameters

All samples were analyzed in the same laboratory, complete blood count were determined using a Sysmex XN-1000 (Sysmex Corporation, Kobe, Japan) analyzer. Biochemical parameters were analyzed using venous blood samples collected during outpatient evaluations after a 12-hour fasting period. Patients who underwent sleeve gastrectomy were subdivided into nondiabetic, prediabetic and diabetic subgroups according to HbA1c value (HbAc1<5.7; 5.7-6.4 and >6.5 respectively).

Statistical analysis

All data were analyzed with IBM SPSS Statistics for Windows 20.0 (IBM Corp., Armonk, NY, USA). Numerical data determined to be normally distributed based on the results of Kolmogorov-Smirnov tests are given as mean and standard deviation (SD) values while non-normally distributed variables are given as median (min-max). For comparisons between groups, Student T-test and Mann-Whitney U test for two group and ANOVA test and Kruskal-Wallis-H test for three group were used in line with the normality of the considered distribution. Categorical variables are given as numbers and percentages, and inter-group comparisons were conducted with Chi-square and Fisher exact tests. Changes in MPV levels during the follow-up period were assessed using the paired sample t-test or repeated measures ANOVA. Pearson or Spearman correlation analyses were applied to evaluate the relationships between numerical variables, depending on the normality of the distribution. Significance was accepted at $P < 0.05$ (*) for all statistical analyses.

Results

The mean age was similar between the morbidly obese group and the control group (35.9 ± 9.5 vs. 36.3 ± 7.2, p = 0.780). The ratio of female was higher in the morbidly obese group compared to control group (82% vs %22.6, p = 0.001). The baseline MPV values were comparable between morbidly obese group and control group (8.8 ± 1.8 vs. 8.6 ± 1.2, p = 0.283). The demographic and laboratory findings of study population are shown in Table 1.

Table 1. Demographic and laboratory findings of study population.

Variables	Morbidly obese group n = 328	Control group n = 53	P-value
Age, years	35.9 ± 9.5	36.3 ± 7.2	0.780
Gender, n (%)			
Male	59 (18.0)	41 (77.4)	0.001*
Female	269 (82.0)	12 (22.6)	
Weight, kg	127.6 ± 18.5	74.0 ± 9.6	<0.001*
BMI, kg/m2	46.4 ± 6.4	26.2 ± 2.7	<0.001*
HbA1c, %	6.0 ± 0.3	5.0 ± 0.3	<0.001*
MPV, fL	8.6 ± 1.2	8.8 ± 1.8	0.283

Data are mean ± standard deviation or number (%). *p<0.05 indicates statistical significance. Abbreviations: BMI, body mass index; HgA1c, Hemoglobin A1c; MPV, mean platelet volume.

BMI levels significantly decreased in morbidly obese patients following sleeve gastrectomy across all follow-up periods (Baseline: 46.4 ± 6.4 vs. 1st month: 41.6 ± 6.3 vs. 3rd month 38.6 ± 6.4 vs. 12th month: 32.8 ± 6.8, p < 0.001) (Table 2).

In control group, there was no significant change in MPV levels during the 12-month follow-up. In morbidly obese group, mean MPV levels at the 1st and 3rd months post-surgery were similar, showing an increase compared to baseline levels. At the 12th month, mean MPV levels tended to decrease, becoming comparable to baseline values (Figure 1) (Table 3).

Table 2. Changes in BMI levels in morbidly obese patients after sleeve gastrectomy.

Follow-up time	BMI	P-value
Baseline	46.4 ± 6.4 bcd	<0,001*
1 month	41.6 ± 6.3 acd	
3 months	38.6 ± 6.4 abd	
12 months	32.8 ± 6.8 abc	

Data are mean ± standard deviation. *p<0.05 indicates statistical significance. a vs. baseline, b vs. 1 months, c vs. 3 months, d vs. 12 months. Abbreviations: BMI, body mass index

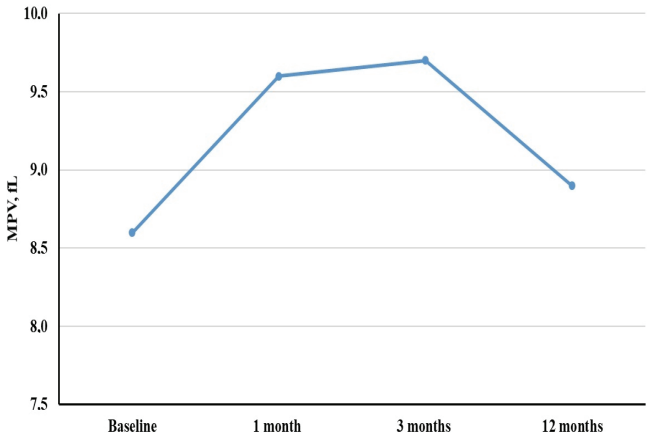

Figure 1. Postoperative variations in MPV levels among morbidly obese patients.

In morbidly obese patients, there was no significant association between baseline BMI and baseline MPV levels. A negative correlation was found between the change in MPV levels and the change in BMI levels at the 1st month ($r = -0.298$; $p = 0.008$) and 3rd month ($r = -0.307$; $p < 0.001$) after surgery. A positive correlation was found between the change in BMI levels and MPV levels at the 12th month ($r = 0.268$; $p = 0.025$)

Discussion

The main findings of this study are as follows: 1) An increase in MPV levels was observed in the short term after sleeve gastrectomy in morbidly obese patients, which negatively correlated with BMI reduction. 2) At the 12th month post-surgery, a decrease in MPV levels was observed, which showed a positive correlation with decreased BMI levels.

In a study conducted by Kutlutürk et al. on 205 morbidly obese patients who underwent laparoscopic sleeve gastrectomy, it was reported that platelet counts decreased, while MPV levels increased during the 6-month after sleeve gastrectomy [18]. In a study by Aykota et al. on 252 morbidly obese patients who underwent laparoscopic sleeve gastrectomy, the patients were followed for 12 months, and similar results were reported [20]. Raoux et al. investigated changes in platelet counts and MPV following bariatric surgery in 128 obese patients [17]. In their study, 90 patients underwent Roux-en-Y gastric bypass surgery, while 38 patients had sleeve gastrectomy. In their study, they reported that MPV increased at the 3rd and 6th months across the entire population and returned to baseline levels by the 12th month. Additionally, they found no significant difference in MPV variations between the two surgical groups [17]. In this study, MPV levels reached their peak at the 1st and 3rd months following sleeve gastrectomy, but were similar to baseline levels over the 12-month period.

Previous studies have reported conflicting results regarding the relationship between weight loss and MPV levels [20-24]. These conflicting results may be attributed to differences in study design, patient populations, or the length of follow-up periods. Variations in the timing of MPV measurements, the degree of weight loss, and the presence of comorbid conditions could also contribute to these discrepancies. Kutlutürk et al. have reported that the increase in MPV levels after LSG was not correlated with a decrease in BMI [18]. Raoux et al. have reported that changes in MPV are correlated with weight loss, especially during rapid weight loss [17]. In the present study, although there was a decrease in BMI levels in the short term following sleeve gastrectomy, MPV levels increased. On the other hand, by the 12th month post-surgery, both BMI and MPV levels had significantly decreased. This could be associated with some postoperative factors. Firstly, the rapid restriction of gastric capacity and loss of appetite after surgery prevent patients from maintaining proper nutrition [25, 26]. It was reported that calorie intake was 30% lower in postoperative 6 weeks, 16% in 1 year and 9% in 2 years compared to preoperative [27]. In a study assessing the impact of various weight loss therapies on MPV, patients followed either a low-calorie diet or a nutritionally

Table 3. Postoperative MPV change in morbidly obese group and control group.

Groups / MPV levels	Baseline	1 month	3 months	12 months	P-value
Morbidly obese	8.6 ± 1.2 bc	9.6 ± 1.4 ad	9.7 ± 1.6 ad	8.9 ± 1.2 bc	<0.001*
Control	8.8 ± 1.8	-	-	8.9 ± 1.6	0.730

Data are mean ± standard deviation. *p<0.05 indicates statistical significance. a vs. baseline, b vs. 1 months, c vs. 3 months, d vs. 12 months. Abbreviations: MPV, mean platelet volume.

complete very low-calorie diet (VLCD) for 8 weeks, followed by a 40-week maintenance period. In both groups, MPV temporarily increased during the 8-week diet phase. By the end of the 48 weeks, MPV had returned to baseline levels. The VLCD group exhibited a smaller change in MPV. However, it was emphasized that there is no relationship between the decrease in MPV and weight loss [28]. This suggests that caloric restriction and fasting may temporarily alter platelet activity and function, possibly influencing MPV levels. Nutritional deficiency has been reported to cause autophagy in platelets, both in animal studies and in humans [29]. Caloric restriction activates autophagy, a catabolic process that helps platelets maintain their function under nutrient-limited conditions by recycling damaged cellular components. This autophagy mechanism plays a crucial role in platelet survival, particularly during periods of fasting or nutritional deficiency. It may also explain the changes in MPV observed during the postoperative period following bariatric surgery, when calorie intake is significantly restricted. On the other hand, thrombocytopenia is a common finding in anorexia nervosa and it has been shown to increase the platelet distribution width, which is anisocytosis indicator [30].

In our study, the increase in MPV peaked between the 1st and 3rd months post-surgery, when calorie intake was highly restricted and weight loss was at its fastest. Another factor influencing the MPV trajectory in patients undergoing sleeve gastrectomy could be ghrelin [31, 32]. Ghrelin is a gut hormone that is mainly secreted by the stomach cell (and other cells) to increase appetite and energy balance. The acetylated form of ghrelin (AG) is known for its cardioprotective, anti-platelet, and anti-thrombotic properties [33]. During sleeve gastrectomy, a significant portion of the stomach, including the ghrelin-producing cells in the fundus, is removed, leading to a substantial decrease in circulating AG levels [34, 35]. While this reduction aids in weight loss, it may increase the risk of platelet aggregation and thrombosis due to its impact on platelet metabolism [33]. The postoperative decrease in platelet count and the negative correlation between platelet count and MPV suggest that younger platelets are in circulation [18, 24].

The current study had several important limitations. The study primarily had a single-center, retrospective design and involved a comparatively small cohort of subjects. It was based on a single-center, retrospective design. Although the sample size was similar to or relatively larger than previous studies, the follow-up period for patients was limited to 1 year. Additionally, our study only examined MPV levels. Changes in platelet count or its indices were not evaluated.

Conclusion

The sleeve gastrectomy significantly affects MPV values, with these changes closely associated with BMI reductions. MPV may serve as a useful biomarker for monitoring postoperative metabolic adjustments and potential thrombosis risk in morbidly obese patients.

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Conflicts of Interest

The authors declare they have no conflicts of interest.

Ethics Approval

The study was performed in accordance with the Declaration of Helsinki, and was approved by the Fatih Sultan Mehmet Training and Research Hospital Clinical Research Ethics Committee(Date: 27.10.2014, Decision No: 2014/9).

Informed Consent

Informed consent was obtained from all patients.

Availability of Data and Material

The data that support the findings of this study are available on request from the corresponding author.

Authors' contribution

Concept – S.A.K. and A.Ö, Design- S.A.K. and A.Ö; Data collection and/or processing - S.A.K., A.B.K., Y.G., N.O., and A.Ö; Analysis and/or interpretation - S.A.K., A.B.K., Y.G., N.O., and A.Ö; Writing – S.A.K., Critical review- A.B.K., Y.G., N.O., and A.Ö. All authors read and approved the final version of the manuscript.

References

1. Scridon A. Platelets and Their Role in Hemostasis and Thrombosis-From Physiology to Pathophysiology and Therapeutic Implications. Int J Mol Sci. 2022;23(21) DOI: 10.3390/ijms232112772.
2. Gasparyan AY, Ayvazyan L, Mikhailidis DP, and Kitas GD. Mean platelet volume: a link between thrombosis and inflammation? Curr Pharm Des. 2011;17(1):47-58. DOI: 10.2174/138161211795049804.
3. Shah B, Sha D, Xie D, Mohler ER, 3rd, and Berger JS. The relationship between diabetes, metabolic syndrome, and platelet activity as measured by mean platelet volume: the National Health And Nutrition Examination Survey, 1999-2004. Diabetes Care. 2012;35(5):1074-8. DOI: 10.2337/dc11-1724.

4. Gulcan M, Varol E, Etli M, Aksoy F, and Kayan M. Mean platelet volume is increased in patients with deep vein thrombosis. Clin Appl Thromb Hemost. 2012;18(4):427-30. DOI: 10.1177/1076029611427437.
5. Park Y, Schoene N, and Harris W. Mean platelet volume as an indicator of platelet activation: methodological issues. Platelets. 2002;13(5-6):301-6. DOI: 10.1080/0953710022201483332.
6. Handtke S and Thiele T. Large and small platelets-(When) do they differ? J Thromb Haemost. 2020;18(6):1256-67. DOI: 10.1111/jth.14788.
7. Furman-Niedziejko A, Rostoff P, Rychlak R, et al. Relationship between abdominal obesity, platelet blood count and mean platelet volume in patients with metabolic syndrome. Folia Med Cracov. 2014;54(2):55-64.
8. Chu SG, Becker RC, Berger PB, et al. Mean platelet volume as a predictor of cardiovascular risk: a systematic review and meta-analysis. J Thromb Haemost. 2010;8(1):148-56. DOI: 10.1111/j.1538-7836.2009.03584.x.
9. Braekkan SK, Mathiesen EB, Njolstad I, Wilsgaard T, Stormer J, and Hansen JB. Mean platelet volume is a risk factor for venous thromboembolism: the Tromso Study, Tromso, Norway. J Thromb Haemost. 2010;8(1):157-62. DOI: 10.1111/j.1538-7836.2009.03498.x.
10. Coban E, Yilmaz A, and Sari R. The effect of weight loss on the mean platelet volume in obese patients. Platelets. 2007;18(3):212-6. DOI: 10.1080/09537100600975362.
11. Coban E, Ozdogan M, Yazicioglu G, and Akcit F. The mean platelet volume in patients with obesity. Int J Clin Pract. 2005;59(8):981-2. DOI: 10.1111/j.1742-1241.2005.00500.x.
12. Ding Q, Wang F, Guo X, and Liang M. The relationship between mean platelet volume and metabolic syndrome in patients with type 2 diabetes mellitus: A retrospective study. Medicine (Baltimore). 2021;100(13):e25303. DOI: 10.1097/MD.0000000000025303.
13. Furuncuoglu Y, Tulgar S, Dogan AN, Cakar S, Tulgar YK, and Cakiroglu B. How obesity affects the neutrophil/lymphocyte and platelet/lymphocyte ratio, systemic immune-inflammatory index and platelet indices: a retrospective study. Eur Rev Med Pharmacol Sci. 2016;20(7):1300-6.
14. Esen B, Atay AE, Gunoz N, et al. The relation of mean platelet volume with microalbuminuria and glomerular filtration rate in obese individuals without other metabolic risk factors: the role of platelets on renal functions. Clin Nephrol. 2015;83(6):322-9. DOI: 10.5414/CN108534.
15. Park BJ, Shim JY, Lee HR, Jung DH, Lee JH, and Lee YJ. The relationship of platelet count, mean platelet volume with metabolic syndrome according to the criteria of the American Association of Clinical Endocrinologists: a focus on gender differences. Platelets. 2012;23(1):45-50. DOI: 10.3109/09537104.2011.589014.
16. Yilmaz MA, Duran C, and Basaran M. The mean platelet volume and neutrophil to lymphocyte ratio in obese and lean patients with polycystic ovary syndrome. J Endocrinol Invest. 2016;39(1):45-53. DOI: 10.1007/s40618-015-0335-2.
17. Raoux L, Moszkowicz D, Vychnevskaia K, et al. Effect of Bariatric Surgery-Induced Weight Loss on Platelet Count and Mean Platelet Volume: a 12-Month Follow-Up Study. Obes Surg. 2017;27(2):387-93. DOI: 10.1007/s11695-016-2292-z.
18. Kutluturk F and Ozsoy Z. Effect of Sleeve Gastrectomy on Platelet Counts and Mean Platelet Volumes. Obes Surg. 2018;28(10):3159-64. DOI: 10.1007/s11695-018-3287-8.
19. Melissas J. IFSO guidelines for safety, quality, and excellence in bariatric surgery. Obes Surg. 2008;18(5):497-500. DOI: 10.1007/s11695-007-9375-9.
20. Aykota MR, Yilmaz S, Atabey M, Ozgen U, and Simsek S. Effect of sleeve gastrectomy on the neutrophil-to-lymphocyte ratio, the platelet-to-lymphocyte ratio, platelet counts, and mean platelet volumes. Indian Journal of Surgery. 2021;83(1):261-67.
21. Zhou L, Lin S, Zhang F, et al. The Correlation Between RDW, MPV and Weight Indices After Metabolic Surgery in Patients with Obesity and DM/IGR: Follow-Up Observation at 12 Months. Diabetes Ther. 2020;11(10):2269-81. DOI: 10.1007/s13300-020-00897-9.
22. Felemban S and Hamouda AF. A pilot study of diet lifestyle on complete blood picture, elements, and biological profile in females. Trends in Immunotherapy. 2024;8(2):6766.
23. Öztürk G, Ak MA, and Ertop S. The Association Between Weight Loss and Platelet Markers in Morbidly Obese Patients. Dicle Tıp Dergisi. 2021;48(4):754-60.
24. Sen O, Oray S, Calikoglu I, Sekmen U, and Turkcapar AG. Effect of laparoscopic sleeve gastrectomy on platelet count and mean platelet volume. J Minim Access Surg. 2023;19(4):489-92. DOI: 10.4103/jmas.jmas_301_22.
25. Benaiges D, Mas-Lorenzo A, Goday A, et al. Laparoscopic sleeve gastrectomy: More than a restrictive bariatric surgery procedure? World J Gastroenterol. 2015;21(41):11804-14. DOI: 10.3748/wjg.v21.i41.11804.

26. Melissas J, Koukouraki S, Askoxylakis J, et al. Sleeve gastrectomy: a restrictive procedure? Obes Surg. 2007;17(1):57-62. DOI: 10.1007/s11695-007-9006-5.

27. Laurenius A, Larsson I, Melanson KJ, et al. Decreased energy density and changes in food selection following Roux-en-Y gastric bypass. Eur J Clin Nutr. 2013;67(2):168-73. DOI: 10.1038/ejcn.2012.208.

28. Toplak H and Wascher TC. Influence of weight reduction on platelet volume: different effects of a hypocaloric diet and a very low calorie diet. Eur J Clin Invest. 1994;24(11):778-80. DOI: 10.1111/j.1365-2362.1994.tb01076.x.

29. Paul M, Hemshekhar M, Kemparaju K, and Girish KS. Aggregation is impaired in starved platelets due to enhanced autophagy and cellular energy depletion. Platelets. 2019;30(4):487-97. DOI: 10.1080/09537104.2018.1475630.

30. Oswiecimska J, Malczyk Z, Szymlak A, et al. Changes in Platelet Count and Size Indices in Adolescent Patients With Anorexia Nervosa. Clin Appl Thromb Hemost. 2017;23(6):562-66. DOI: 10.1177/1076029617705727.

31. Farey JE, Preda TC, Fisher OM, et al. Effect of Laparoscopic Sleeve Gastrectomy on Fasting Gastrointestinal, Pancreatic, and Adipose-Derived Hormones and on Non-Esterified Fatty Acids. Obes Surg. 2017;27(2):399-407. DOI: 10.1007/s11695-016-2302-1.

32. Zhao X, Han Q, Gang X, et al. The Role of Gut Hormones in Diet-Induced Weight Change: A Systematic Review. Horm Metab Res. 2017;49(11):816-25. DOI: 10.1055/s-0043-115646.

33. Morsy MD. Hemostatic effect of acylated ghrelin in control and sleeve gastrectomy-induced rats: mechanisms of action. Arch Physiol Biochem. 2020;126(1):31-40. DOI: 10.1080/13813455.2018.1489849.

34. Tymitz K, Engel A, McDonough S, Hendy MP, and Kerlakian G. Changes in ghrelin levels following bariatric surgery: review of the literature. Obes Surg. 2011;21(1):125-30. DOI: 10.1007/s11695-010-0311-z.

35. Elbatarny HS, Netherton SJ, Ovens JD, Ferguson AV, and Maurice DH. Adiponectin, ghrelin, and leptin differentially influence human platelet and human vascular endothelial cell functions: implication in obesity-associated cardiovascular diseases. Eur J Pharmacol. 2007;558(1-3):7-13. DOI: 10.1016/j.ejphar.2006.11.052.