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ORIGINAL CONTRIBUTIONS

Which Bariatric Procedure Is the Most Popular in the World? A Bibliometric Comparison

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Abstract

Objective This study aims to make a bibliometric analysis of the most commonly performed bariatric procedures between the years 2006 and 2016 and identify the most popular procedure in the field of bariatric surgery (BS).

Background Despite the fact that BS popularity has been increasing considerably in recent years, the literature indicates insufficient information regarding the comparison of the methods used in BS.

Methods The terms "Sleeve Gastrectomy," "Gastric Bypass," or "Gastric Band" were searched in Web of Science for the years between 1980 and 2016. All the publications found were subjected to bibliometric analysis.

Results WoS database included 3501 publications about the sleeve gastrectomy keyword, 7278 publications about the gastric bypass keyword, and 2692 publications about the gastric band keyword. USA was found to be the most active country in all methods, and the authors who had most publications were Gagner M (64, 1.8%) for sleeve gastrectomy, Le Roux CW (83, 1.1%) for gastric bypass, and O'brien PE (50, 1.9%) for gastric band. "Obesity Surgery" was the journal that contributed most to the literature in all three obesity surgery procedures.

Conclusion Despite the fact that the top procedure was Roux-en-Y gastric bypass in terms of bibliometrics, the most popular procedure was found to be sleeve gastrectomy. According to the percentage of the increase in publications and citations, sleeve gastrectomy was found to be the method which showed the highest increase rates in recent years.

Keywords Bariatric surgery · Obesity surgery · Procedures · Bibliometrics

Introduction

Obesity is defined as the abnormal or excessive fat accumulation that may impair health. Superalimentation and malnutrition, sedentary lifestyle, and environmental factors in the developing and developed countries have caused a rapid increase in obesity, which is a factor that increases health expenses dramatically [1]. As a result, the increase in obesity rates has also brought a number of various comorbid conditions such as diabetes, stroke, cardiovascular diseases, gallbladder disease, osteoarthritis, sleep apnea, and certain types of cancer; it also causes negative effects on quality of life [2, 3].

Non-surgical (e.g., diet therapy, pharmaceutical therapy, and lifestyle modification) and surgical approaches are utilized in order to manage obesity. Bariatric surgery (BS) is considered for patients with severe obesity (body mass index ≥ 40, or > 35 kg/m^2 with comorbidities) [4]. Today, BS is considered the most effective treatment option in morbid obesity. In comparison to non-surgical interventions, BS enables better improvement weight loss outcomes and comorbidities related to obesity, no matter what type of surgical procedure is used [3, 5]. Today, Roux-en-Y gastric bypass (RYGB), sleeve gastrectomy (SG), and adjustable gastric banding (AGB) are the most commonly performed three operations in the world for the management of morbid obesity [4, 6, 7].

Beside the studies about the comparison of the number, frequency, and metabolic activities of bariatric procedures, the literature consists of a number of bibliometric studies [8–10]. Bibliometrics is a numerical analysis which can be used to assess the popularity and effects of publications as

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well as authors and institutions in a specific field within in a specific period of time [11, 12]. As for citation analysis, it is a bibliometric method which is based on the demonstration of the citations and relationships among scientific documents through a web or graphic; it shows the relationships between authors or publications [13, 14]. Bibliometric methods have now become high quality, reliable, and very informative in research evaluation practice for evaluating the performance of the publications, and following, ranking, and mapping the authors and institutions.

The results of the International Federation for the Surgery of Obesity and Metabolic Diseases (IFSO) email questionnaire survey indicated that 468,609 bariatric procedures (95.7% laparoscopically) were performed in the world in 2013, and the highest number was found to be in the USA/Canada region [6]. A significant increase (from 0 to 37%) was reported in the prevalence of SG between the years 2003 and 2013; there was also a decrease in AGB, which had its peak in 2008. These results were in line with the IFSO global survey, which also indicated a decrease in RYGB practice, an increase followed by a steep decrease in AGB and a notable increase in SG [6]. While another study reported a slight decline in RYGB rates, there was a linear increase in SG. Besides, AGB was found to demonstrate a significant decrease over the study period which was between 2010 and 2014 [15]. Primarily because it has a number of advantages, SG is today regarded as the principal laparoscopic bariatric procedure [16–18].

No studies in the literature seem to have investigated how the recent changes in the prevalence of BS procedures are reflected on the number of publications and citations. This study aims to compare the most commonly performed bariatric procedures between the years 2000 and 2016 in light of bibliometric data and identify the most popular procedure in the field of BS.

Materials and Methods

The documents used in this study were obtained from Thomson Reuters Web of Science (WoS; Thomson Reuters, New York, NY, USA) on first of November, 2017. "Sleeve gastrectomy," "gastric bypass," and "gastric band" BS methods were used as keywords for the bibliometric and other analyses. The results obtained through the "gastric bypass" keyword did not include the ones which involved "mini gastric bypass" (TITLE: ("sleeve gastrectomy") OR TITLE: ("gastric bypass") NOT TITLE: ("mini gastric bypass") OR TITLE: ("gastric band") OR TITLE: ("gastric banding")). The study involved the documents published between 1980 and 2016. Bibliometric analyses were performed using VOSviewer (version 1.6.5) package programming. Map chart free resource (https://mapchart.net/detworld.html) was utilized for the world map. The circle size in bibliometric maps gets bigger as the number of the use of keywords increases. Colors show the number of citations the keywords receive, and the number of citations of the publication with that keyword increases from blue to red. Lines get thicker according to the number of keywords used together.

Results

Search results performed with the sleeve gastrectomy keyword in WoS database indicated a total number of 3501 publications (TITLE: ("sleeve gastrectomy")). The total *h* index of the 3501 publications was 76; the average number of citations per publication was 8.38; and the total number of citations was 29,349 (without self-citations 15,296). Of these publications, 1846 (52.7%) were meeting abstracts, 1274 (36.4%) were articles, 157 (4.5%) were editorial materials, 109 (3.1%) were letters, and 84 (2.4%) were reviews. Search results performed with the gastric bypass keyword (TITLE: ("gastric bypass") NOT TITLE: ("mini gastric bypass")) indicated a total number of 7278 publications. The total *h* index of the 7278 publications was 114; the average citation per publication was 12.35; and the total number of citations was 89,907 (without self-citations 63,748). Of these publications, 3288 (45.2%) were meeting abstracts, 3127 (43.0%) were articles, 417 (5.7%) were editorial materials, 361 (5.0%) were proceedings papers, 255 (3.5%) were letters, and 147 (2.0%) were reviews. Search results with the gastric band keyword (("gastric band") OR TITLE: ("gastric banding")) indicated 2692 publications. The total *h* index of the 2692 publications were 70; the average citation per publication was 10.68; and the number of total citations was 28,762 (without self-citations 19,818). Of these publications, 1234 were (45.8%) meeting abstracts, 1168 (43.4%) were articles, 145 (5.4%) were editorial materials, 115 (4.3%) were proceedings papers, 78 (2.9%) were letters, and 41 (1.5%) were reviews.

Research Areas

Of all the publications about SG, 2967 (84.7%) were published in the field of surgery, 173 (4.9%) were in gastroenterology hepatology, 154 (4.4%) were in endocrinology metabolism, 77 (2.2%) were in internal medicine, and 63 (1.8%) were in nutrition dietetics research fields. As for the publications about RYGB, 4987 (68.5%) were in the surgery field, 800 (11.0%) were in endocrinology metabolism field, 713 (9.8%) were in gastroenterology hepatology field, 378 were (5.2%) in the nutrition dietetics, and 182 (2.5%) were in general internal medicine research fields. Of the publications about AGB, 2118 (78.7%) were in surgery research field, 184 (6.8%) were in endocrinology metabolism, 176 (6.5%) were in gastroenterology hepatology,

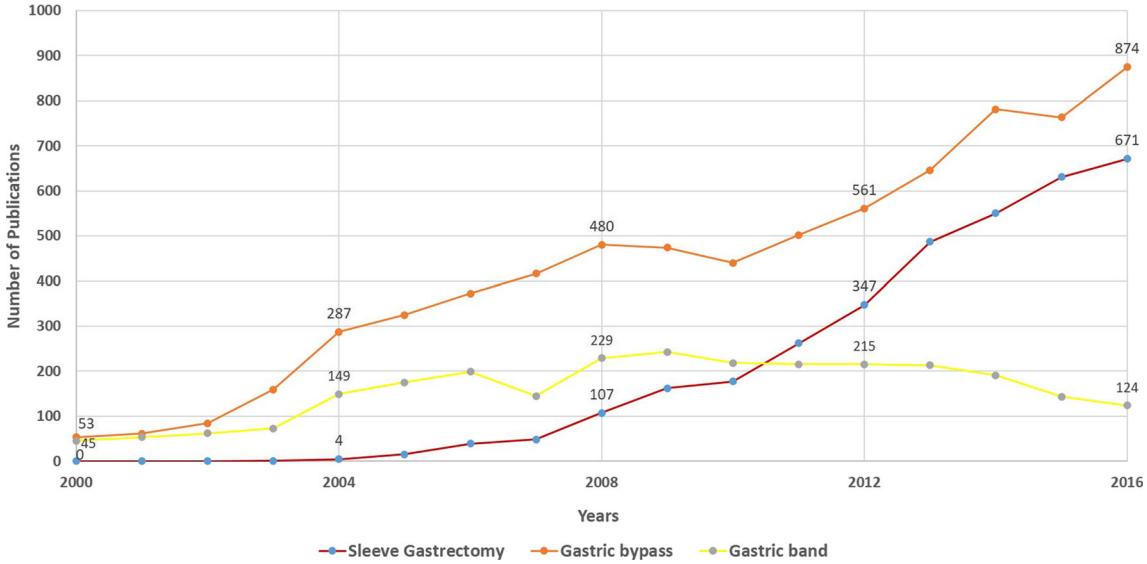

Fig. 1 Distribution of publication numbers of surgical types according to years

98 (3.6%) were in nutrition dietetics, and 79 (2.9%) were in general internal medicine.

Number of Publications and Citations According to Years; Productivity

Figure 1 demonstrates the distribution of the number of publications about the surgery procedures according to years, and the percentage changes of the number of publications about the three procedures in a year are given in Fig. 2. An analysis of Fig. 1 indicates that while there has been a decrease in the number of publications about AGB method in recent years, an increase is noted in the number of publications about the SG and RYGB procedures. An analysis of Fig. 2 indicates that there has been a proportional increase in the publications about SG within a year especially in recent years; RYGB has showed a stable increase; and AGB has decreased. Figure 3 demonstrates the distribution of the number of citations about the surgical procedures according to years, and Fig. 4 demonstrates the percentage changes of the number of citations of three procedures within a year. An analysis of Figs. 3 and 4 together indicates that parallel to the implications

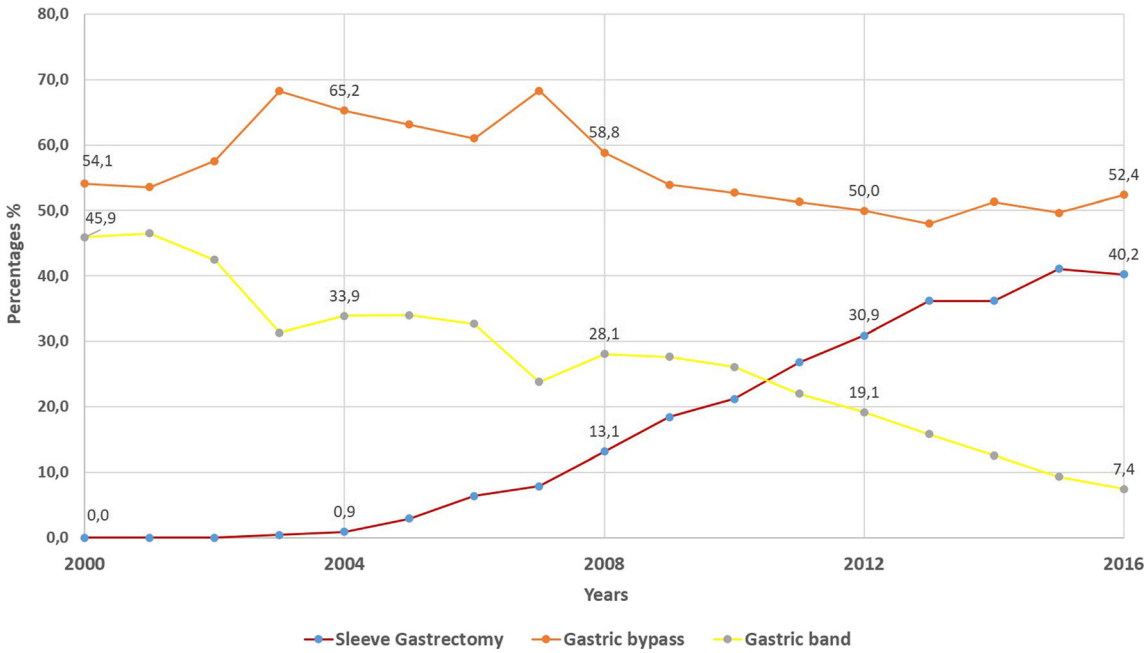

Fig. 2 Percent change in the number of publications made in surgical types during the year

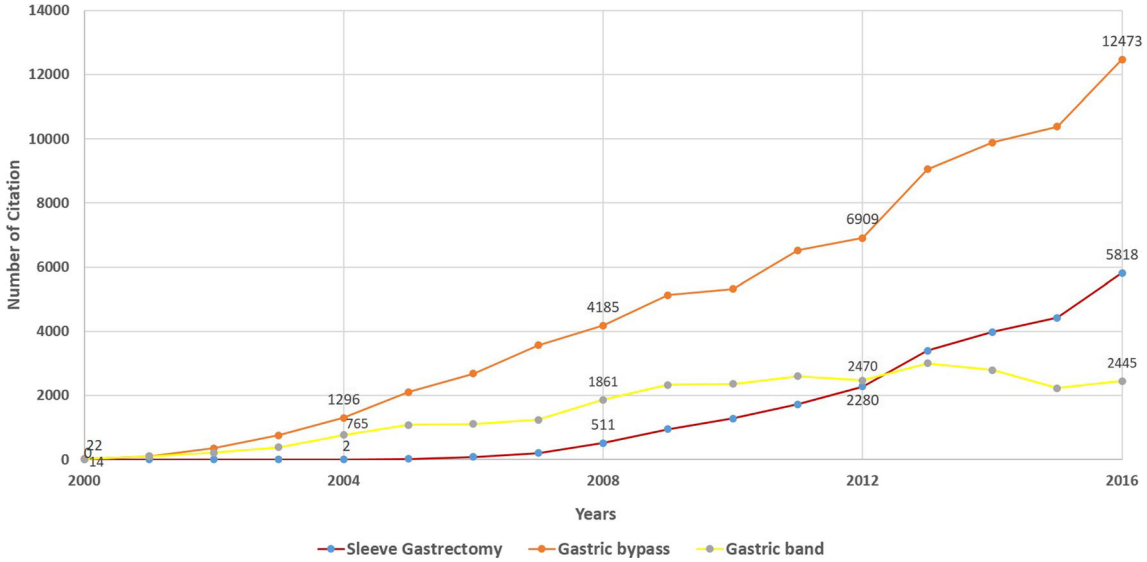

Fig. 3 Distribution of citation numbers of surgical types according to years

of the number of publications, SG is the procedure which has demonstrated also the highest proportional increase in the number of citations in recent years.

Active Countries

The distribution of the surgical procedures according to countries (top 15 countries) is demonstrated in Fig. 5. Top countries in SG publications were the USA, France, India, Italy, and Spain. USA, Brazil, England, France, and Spain respectively were the top countries in the RYGB procedure. As for the AGB procedure, the top 5 countries were the USA, Italy, England, France, and Australia. Other countries are shown in Fig. 5.

The number of publications about the three different surgical procedure publications in one country was found; the procedure with most publications was shown with different colors in the world map (SG; red, RYGB; orange, AGB; yellow), and the procedure which was focused most by the countries was demonstrated in the world map (see Fig. 6).

Active Authors

The top 10 active authors who produced most publications according to surgical procedures are shown in Table 1. An

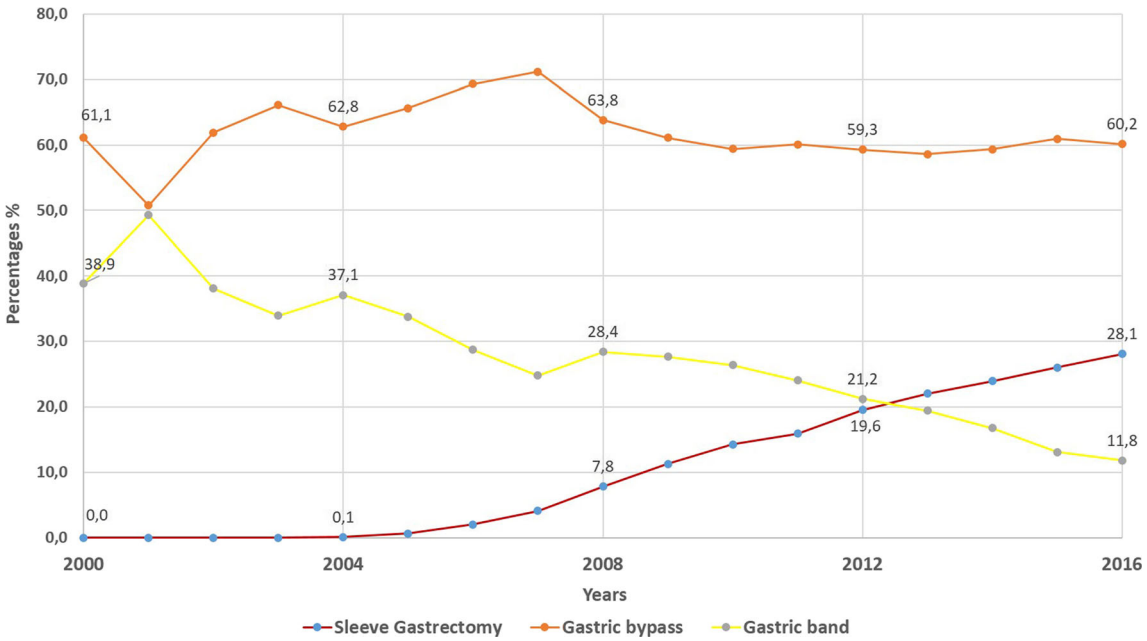

Fig. 4 Percent change in the number of citations made in surgical types during the year

Fig. 5 Distribution of surgical types according to countries (first 15 countries)

analysis of Table 1 indicates that the most active authors in SG, RYGB, AGB topics were Gagner M (64, 1.8%), Le Roux CW (83, 1.1%), and O'brien PE (50, 1.9%) respectively. The other 10 active authors are shown in Table 1.

Active Journals

The top 10 active journals that had most publications according to the surgical procedures are shown in Table 2. An

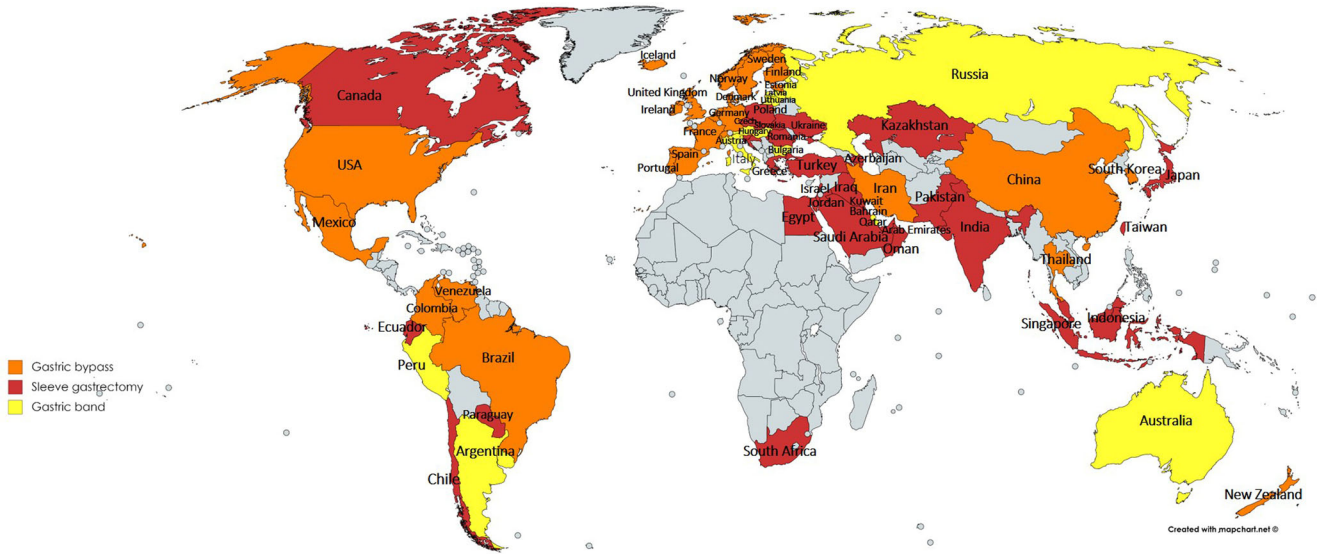

Fig. 6 Distribution of the largest number of surgical publications in a country

Table 1 Active authors according to surgical methods in bariatric surgery

Sleeve gastrectomy			Gastric bypass			Gastric band		
Authors	RC	C	Authors	RC	C	Authors	RC	C
Gagner M	64	2093	Le Roux CW	83	2178	O'brien PE	50	2950
Dhahri A	54	300	İkramuddin S	76	3213	Aigner F	38	882
Rebibo L	49	182	Thompson CC	76	525	Super P	37	91
Regimbeau JM	48	468	Holst JJ	75	2020	Busetto I	36	942
Basso N	41	989	Sundbom M	68	1025	Fielding GA	34	741
Casella G	40	959	Bueter	65	1148	Dixon JB	31	2612
Gugenheim J	37	298	Olbers	64	1988	Favretti F	31	721
Rizzello M	37	785	Nguyen NT	58	2941	Pontiroli AE	31	693
Verhaeghe P	35	441	Madsbad S	54	962	Fielding G	31	409
Adamo M	34	88	Dillemans B	54	121	Singhal R	31	91

RC record count, *C* number of citation

analysis of Table 2 indicates that *Obesity Surgery* was the most active journal in all three surgical procedures. *Surgery for Obesity and Related Disease* (*SOARD*) journal was ranked second. *Journal of Obesity Surgery* had 2032 publications about SG, 3145 publications about RYGB, and 1435 publications about AGB.

Citation Analysis

Table 3 demonstrates the top cited publications according to surgical procedures. The top cited publication about SG was the study entitled "Weight loss, appetite suppression, and changes in fasting and postprandial ghrelin and peptide-YY levels after Roux-en-Y gastric bypass and sleeve gastrectomy–A prospective, double blind study" written by Karamanakos Stavros N et al. in 2008 in the journal of *Annals of Surgery*. The top cited study according to years was the article entitled "FXR is a molecular target for the effects of vertical sleeve gastrectomy" written by Ryan Karen K et al. in 2014 in the journal of *Nature* [19]. The top cited publication about RYGB was the study entitled "Plasma ghrelin levels after diet-induced weight loss or gastric bypass surgery" written by Cummings DE et al. and published in the journal of *New England Journal of Medicine* in 2002. The top cited study according to years was "Long-term mortality after gastric bypass surgery" written by Adams Ted D et al. and

Table 2 Active journals according to surgical methods in bariatric surgery

Sleeve gastrectomys			Gastric bypass			Gastric band		
Journals	RC	C	Authors	RC	C	Authors	RC	C
Obesity Surgery	2-0-3-2	13,-483	*Obesity Surgery*	3-1-4-5	25,-828	*Obesity Surgery*	1-4-3-5	11,-464
Surgery for Obesity and Related Diseases	296	4576	*Surgery for Obesity and Related Diseases*	595	7642	*Surgery for Obesity and Related Diseases*	200	2495
Surgical Endoscopy and Other Interventional Techniques	98	2538	*Gastroenterology*	248	640	*Surgical Endoscopy and Other Interventional Techniques*	88	2071
British Journal of Surgery	92	123	*Surgical Endoscopy and Other Interventional Techniques*	201	4950	*British Journal of Surgery*	59	152
Gastroenterology	51	333	*British Journal of Surgery*	165	564	*Gastroenterology*	54	3
International Journal of Surgery	41	142	*Diabetes*	152	715	*International Journal of Obesity*	38	766
Diabetes	29	153	*Obesity*	130	2021	*Annals of Surgery*	32	1743
Surgical Laparoscopy Endoscopy Percutaneous Techniques	27	346	*American Journal of Gastroenterology*	121	260	*Obesity*	26	346
Journal of Laparoendoscopic Advanced Surgical Techniques	25	154	*Journal of the American College of Surgeons*	118	1984	*American Journal of Gastroenterology*	22	0
Journal of Visceral Surgery	22	132	*Gastrointestinal Endoscopy*	89	493	*American Journal of Surgery*	21	531

RC record count, *C* number of citation

Table 3 The most cited publications according to surgical methods in bariatric surgery

Methods	Article	Author	Journal name/Published	Total citation	Average citations per year
Sleeve gastrectomy	Weight loss, appetite suppression, and changes in fasting and postprandial ghrelin and peptide-YY levels after Roux-en-Y gastric bypass and sleeve gastrectomy - A prospective, double blind study	Karamanakos, Stavros N.; Vagenas, Konstantinos; Kafarentzos, Fotis; et al.	*Annals of Surgery*-2008	443	44.30
	A prospective randomized study between laparoscopic gastric banding and laparoscopic isolated sleeve gastrectomy: Results after 1 and 3 years	Himpens, Jacques; Dapri, Giovanni; Cadiere, Guy Bernard	*Obesity Surgery* −2006	384	32.00
	Laparoscopic sleeve gastrectomy as an initial weight-loss procedure for high-risk patients with morbid obesity	Cottam, D; Qureshi, FG; Mattar, SG; et al.	*Surgical Endoscopy and Other Interventional Techniques* −2006	353	29.42
	Sleeve gastrectomy and gastric banding: Effects on plasma ghrelin levels	Langer, FB; Hoda, MAR; Bohdjalian, A; et al.	*Obesity Surgery*-2005	326	40.75
	Long-term Results of Laparoscopic Sleeve Gastrectomy for Obesity	Himpens, Jacques; Dobbeleir, Julie; Peeters, Geert	*Annals of Surgery*-2010	324	24.92
	Improvement in Glucose Metabolism After Bariatric Surgery: Comparison of Laparoscopic Roux-en-Y Gastric Bypass and Laparoscopic Sleeve Gastrectomy A Prospective Randomized Trial	Peterli, Ralph; Woelnerhanssen, Bettina; Peters, Thomas; et al.	*Annals of Surgery*-2009	318	35.33
	International Sleeve Gastrectomy Expert Panel Consensus Statement: best practice guidelines based on experience of >12,000 cases	Rosenthal, Raul J. Group Author(s): Int Sleeve Gastrectomy Expert	*Surgery for Obesity and Related Diseases*-2012	314	52.33
	FXR is a molecular target for the effects of vertical sleeve gastrectomy	Ryan, Karen K.; Tremaroli, Valentina; Clemmensen, Christoffer; et al.	*Nature*-2014	280	70.00
	Laparoscopic sleeve gastrectomy: A multi-purpose bariatric operation	Baltasar, A; Serra, C; Perez, N; et al.	*Obesity Surgery*-2005	279	21.46
	First Report from the American College of Surgeons Bariatric Surgery Center Network Laparoscopic Sleeve Gastrectomy has Morbidity and Effectiveness Positioned Between the Band and the Bypass	Hutter, Matthew M.; Schirmer, Bruce D.; Jones, Daniel B.; et al.	*Annals of Surgery*-2011	254	36.29
Gastric bypass	Plasma ghrelin levels after diet-induced weight loss or gastric bypass surgery.	Cummings, DE; Weigle, DS; Frayo, RS; et al.	*New England Journal of Medicine*-2002	1448	90.50
	Long-term mortality after gastric bypass surgery	Adams, Ted D.; Gress, Richard E.; Smith, Sherman C.; et al.	*New England Journal of Medicine*-2007	1274	115.82
	Outcomes after laparoscopic Roux-en-Y gastric bypass for morbid obesity	Schauer, PR; Ikramuddin, S; Gourash, W; et al.	*Annals of Surgery*-2000	796	44.22
	Human gut microbiota in obesity and after gastric bypass	Zhang, Husen; DiBaise, John K.; Zuccolo, Andrea; et al.	*Proceedings of the National Academy of Sciences of the United States of America*-2009	695	77.22
	Effect of laparoscopic Roux-En-Y gastric bypass on type 2 diabetes mellitus	Schauer, PR; Burguera, B; Ikramuddin, S; et al.	*Annals of Surgery*-2003	680	45.33
	Laparoscopic versus open gastric bypass: A randomized study of outcomes, quality of life, and costs	Nguyen, NT; Goldman, C; Rosenquist, J; et al.	*Annals of Surgery*-2001	614	36.12
	Laparoscopic gastric bypass, Roux en-Y - 500 patients: Technique and results, with 3-60 month follow-up	Wittgrove, AC; Clark, GW	*Obesity Surgery*-2000	516	28.67
	Weight loss, appetite suppression, and changes in fasting and postprandial ghrelin and peptide-YY levels after Roux-en-Y gastric bypass and sleeve gastrectomy - A prospective, double blind study	Karamanakos, Stavros N.; Vagenas, Konstantinos; Kafarentzos, Fotis; et al.	*Annals of Surgery*-2008	438	43.80
	Early experience with two-stage laparoscopic Roux-en-Y gastric bypass as an alternative in the super-super obese patient	Regan, JP; Inabnet, WB; Gagner, M; et al.	*Obesity Surgery*-2003	434	28.93

Table 3 (continued)

Methods	Article	Author	Journal name/Published	Total citation	Average citations per year
	Complications after Laparoscopic gastric bypass - A review of 3464 cases	Podnos, YD; Jimenez, JC; Wilson, SE; et al.	*Archives of Surgery*-2003	406	27.07
Gastric band	Adjustable gastric banding and conventional therapy for type 2 diabetes - A randomized controlled trial	Dixon, John B.; O'brien, Paul E.; Playfair, Julie; et al.	*Jama-Journal of the American Medical Association*-2008	823	82.30
	A prospective randomized study between laparoscopic gastric banding and laparoscopic isolated sleeve gastrectomy: Results after 1 and 3 years	Himpens, Jacques; Dapri, Giovanni; Cadiere, Guy Bernard	*Obesity Surgery*-2006	382	31.83
	Laparoscopic adjustable gastric banding in the treatment of obesity: A systematic literature review	Chapman, AE; Kiroff, G; Game, P; et al.	*Surgery*-2004	336	24.00
	Sleeve gastrectomy and gastric banding: Effects on plasma ghrelin levels	Langer, FB; Hoda, MAR; Bohdjalian, A; et al.	*Obesity Surgery*-2005	322	24.77
	Treatment of mild to moderate obesity with laparoscopic adjustable gastric banding or an intensive medical program - A randomized trial	O'brien, PE; Dixon, JB; Laurie, C; et al.	*Annals of Internal Medicine*-2006	312	26.00
	Gastric banding or bypass? A systematic review comparing the two most popular bariatric procedures	Tice, Jeffrey A.; Karliner, Leah; Walsh, Judith; et al.	*American Journal of Medicine*-2008	277	27.70
	The laparoscopic adjustable gastric band (Lap-Band (R)): A prospective study of medium-term effects on weight, health and quality of life	O'brien, PE; Dixon, JB; Brown, W; et al.	*Obesity Surgery*-2002	267	16.69
	A 10-year experience with laparoscopic gastric banding for morbid obesity: High long-term complication and failure rates	Suter, M.; Calmes, J. M.; Paroz, A.; et al.	*Obesity Surgery*-2006	250	20.83
	Complications after laparoscopic adjustable gastric banding for morbid obesity: Experience with 1,000 patients over 7 years	Chevallier, JM; Zinzindohoue, F; Douard, R; et al.	*Obesity Surgery*-2004	247	17.64
	High failure rate after laparoscopic adjustable silicone gastric banding for treatment of morbid obesity	DeMaria, EJ; Sugerman, HJ; Meador, JG; et al.	*Annals of Surgery*-2001	241	14.18

published in the journal of *New England Journal of Medicine* in 2007. The top cited publication about AGB was the study entitled "Adjustable gastric banding and conventional therapy for type 2 diabetes–A randomized controlled trial" written by Dixon John B et al. and published in *JAMA Journal of the American Medical Association* in 2008. The study was also the top cited publication according to years (see Table 3).

Keyword Analysis; Trend Topics Network visualization maps obtained through the keyword analyses according to surgical procedures are given in Figs. 7, 8, and 9 respectively. Color changes from blue to red show the keywords that are cited more. Besides, Table 4 shows the most frequently used 50 keywords according to procedures.

Discussion

The present study involves trends and change processes about the most frequently used bariatric procedures, and it is the first study which makes a bibliometric comparison in a specific field. BS procedures have gone through a great change process in the last two decades. Factors such as the effectiveness of the procedures in long-term weight loss and obesity-related diseases, rates of complications, and revision requirements could be considered as the causes of this change.

This study found that the publications and citations related to the RYGB procedure were at the top for 16 years. In RYGB procedure, a small pouch from the proximal portion of the stomach is constructed and directly attached to the small intestine. Part of the stomach and duodenum are bypassed [20]. It started to be applied in 1994, and its history is older than the other procedures. It is the most frequently conducted bariatric procedure especially in the USA and in many regions of the world [21]. It is therefore quite natural that with this feature it is the top in terms of the number of publications and citations. A large portion of the stomach is removed in the SG surgical technique, which is one of the newest techniques. However, this procedure does not involve the removal or bypass of the intestines [20]. It was found that the number of SG publications and citations have increased each year since 2003. Specifically, between the years 2008 and 2016, SG

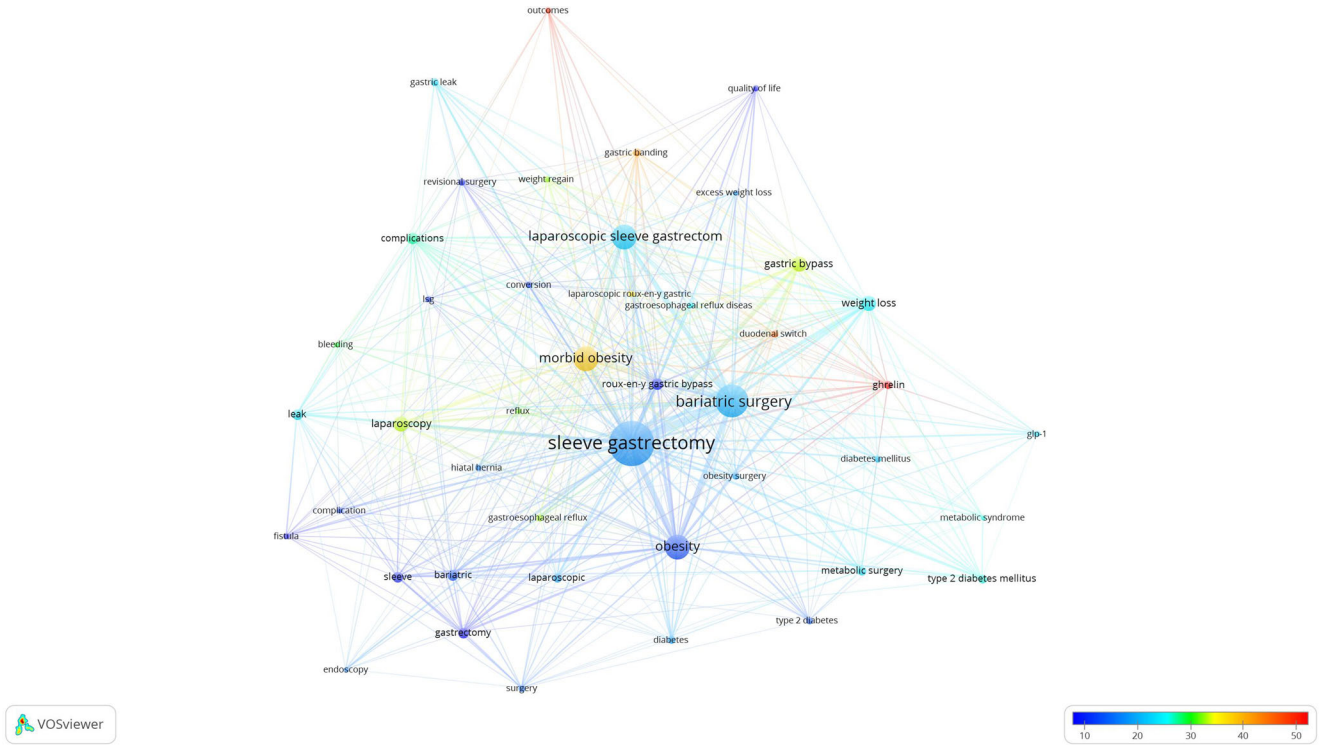

Fig. 7 Keyword analysis for sleeve gastrectomy. Footnote: According to the number of citations received by the intensity of color, the bluish redness increases

publications increased from 13 to 40%, and the number of citations was parallel to the number of publications (from 7.8 to 28.1%). The same period indicated a decrease in the RYGB (−6.4%) and AGB (−20.7%) publication and citation rates. While in 2007, the American Society for Metabolic and Bariatric Surgery (ASMBS) recommended SG only for

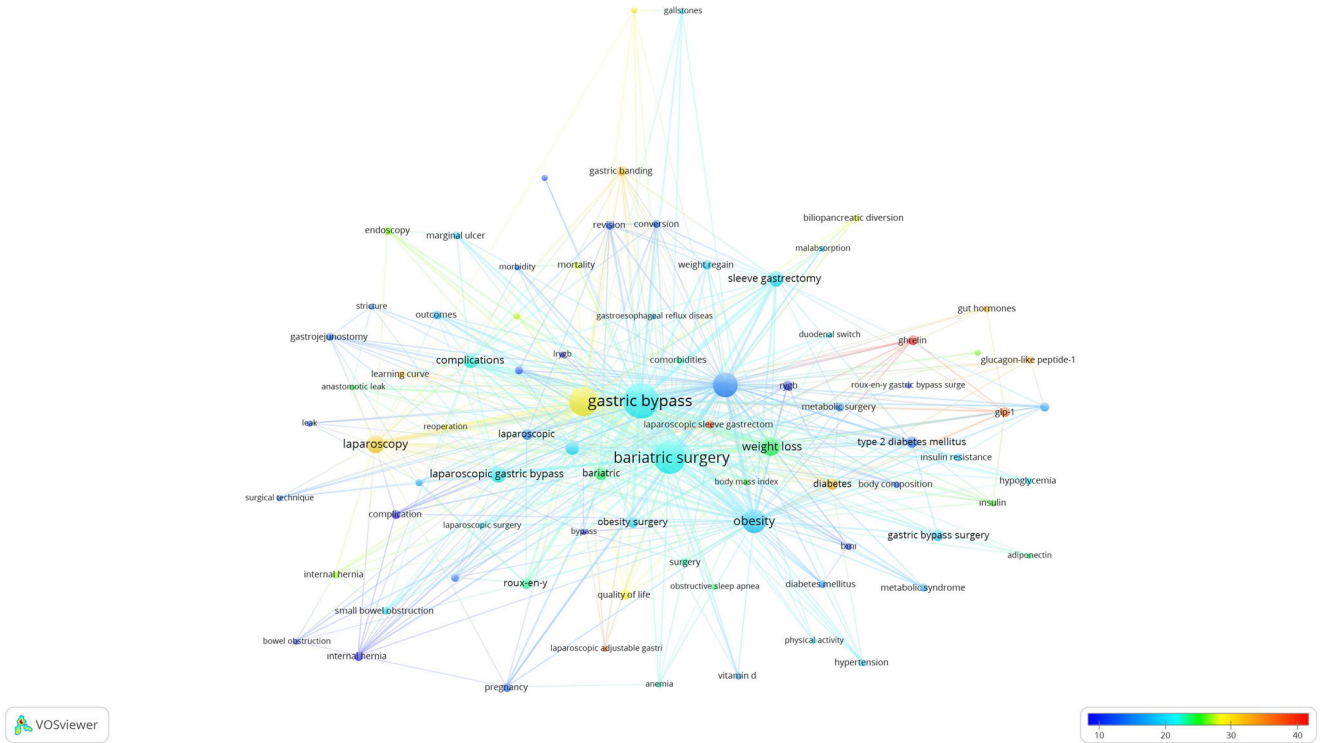

Fig. 8 Keyword analysis for gastric bypass. Footnote: According to the number of citations received by the intensity of color, the bluish redness increases

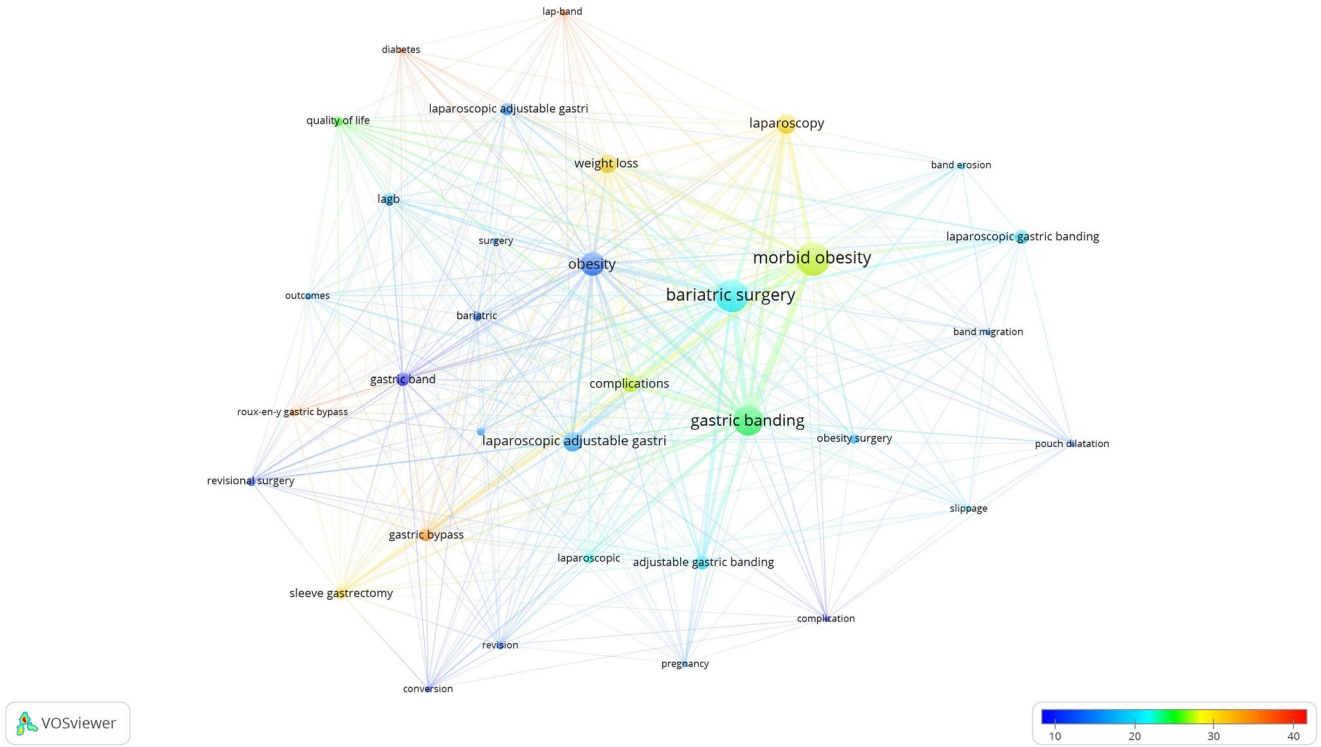

Fig. 9 Keyword analysis for gastric band. Footnote: According to the number of citations received by the intensity of color, the bluish redness increases

carefully selected or super-super obese patients with high risk; in 2010, SG was recommended as first-stage procedure in obese patients with high risk [22, 23]. In 2012, SG was recognized by ASMBS as an acceptable option as a primary bariatric procedure [24]. Following these recommendations, particularly 2013 became the year when SG publications increased most. The factors that led SG to be recognized as a single bariatric procedure included the advantages such as its having positive effects on weight loss and obesity-related comorbidities and enabling low complication and low mortality rates [18, 25]. Beside these factors, reasons for the increase in the popularity of SG also include its being more cost-effective in comparison to RYGB and its being an easier and faster surgical procedure [26]. AGB procedure includes the placement of an inflatable band around the proximal part of the stomach in order to create a small pouch. The band is adjustable according to patients' needs, and hence it is possible increase or decrease the restriction [20]. Primarily because it is reversible and has minimal invasiveness, it has become one of the most frequently implemented procedures for morbid obesity. On the other hand, high failure rates associated with AGB are reported to require revisional operation [27]. A study conducted by Nguyen et al. indicated a decrease in AGB from 23.8% in the fourth quarter of 2008 to 4.1% in the third quarter of 2012 [18]. Other studies conducted in 2013 and 2014 also showed a continued decrease in the number of AGB procedures [6, 15, 28]. Reflection of this decrease in the procedure prevalence is inevitable in terms of the number of publications and citations. This study found an increase in AGB publications until 2009, and it reached the peak value in that year. The following years showed a decline. Between the years 2008 and 2010, which were the years when SG publications exceeded 100 publications, there was a slight decrease in the number of RYGB and AGB publications in comparison to other years. These were the years when the popularity of SG started to increase [6]. Although this study found a decrease in the RYGB publication and citation rates, this decrease was not significant. However, it was noted that there was a decrease in AGB rates together with the increase in SG rates. Hence, we believe that SG decreased the popularity of AGB rather than RYGB.

Recent studies report that SG was performed in European countries in equal numbers, and it was performed more in Asia and USA/Canada; RYGB was performed more in South America. AGB is more popular in Europe, Australia, and South America [6, 29–31]. An analysis of the number of publications and citations based on countries showed similar findings to the number of surgeries. USA and some developed European countries were at the top in all three procedures. USA was reported to be the top country in other bibliometric studies about BS [8–10]. When the huge budget and the great number of research centers allocated for research for obesity in the USA are considered, this finding is somewhat expected. Scandinavian countries had more RYGB publications. AGB publications were most commonly seen in Italy in Europe. Australia was ranked fifth in the number of publications. As

Table 4 Most used 50 keywords according to surgical methods in bariatric surgery

Sleeve gastrectomy		Gastric bypass		Gastric band	
Keyword	O	Keyword	O	Keyword	O
Sleeve gastrectomy	830	Gastric bypass	1231	Morbid obesity	424
Bariatric surgery	449	Bariatric surgery	1010	Bariatric surgery	421
Obesity	261	Morbid obesity	746	Gastric banding	353
Laparoscopic sleeve gastrectomy	253	Roux-en-y gastric bypass	481	Obesity	213
Morbid obesity	252	Obesity	469	Laparoscopic adjustable gastric banding	143
Weight loss	100	Weight loss	244	Laparoscopy	140
Gastric bypass	98	Laparoscopy	207	Weight loss	126
Laparoscopy	95	Laparoscopic gastric bypass	165	Complications	106
Complications	61	Sleeve gastrectomy	141	Laparoscopic gastric banding	81
Roux-en-y gastric bypass	56	Complications	133	Adjustable gastric banding	80
Gastrectomy	54	Laparoscopic Roux-en-y gastric bypass	109	Gastric bypass	72
Bariatric	52	Bariatric	87	Gastric band	66
Leak	50	Gastric bypass surgery	84	Laparoscopic adjustable gastric band	55
Sleeve	49	Diabetes	80	Sleeve gastrectomy	54
Type 2 diabetes mellitus	37	Type 2 diabetes mellitus	70	Lagb	51
Laparoscopic	35	Internal hernia	67		
Metabolic surgery	34	Roux-en-y	69	Quality of life	40
Ghrelin	33	Obesity surgery	66	Bariatric	37
Gastric banding	32	Laparoscopic	63	Obesity surgery	35
Diabetes	30	Rygb	55	Laparoscopic	34
Gastric leak	28	Ghrelin	51	Revisional surgery	29
Obesity surgery	27	Quality of life	50	Adjustable gastric band	27
Duodenal switch	24	Gastric banding	49	Revision	24
Type 2 diabetes	24	Glp-1	49	Lap-band	22
Revisional surgery	23	Weight regain	49	Roux-en-y gastric bypass	21
Surgery	22	Type 2 diabetes	42	Outcomes	20
Gastroesophageal reflux	22	Revision	39	Band erosion	18
Diabetes mellitus	22	Metabolic surgery	39	Conversion	17
Weight regain	21	Outcomes	39	Pouch dilatation	16
Quality of life	21	Complication	39	Slippage	16
Hiatal hernia	20	Endoscopy	38	Band migration	16
Glp-1	20	Pregnancy	37	Pregnancy	16
Complication	19	Insulin resistance	36	Surgery	16
Outcomes	19	Surgery	35	Diabetes	15
LSG	19	Metabolic syndrome	34	Complication	15
Fistula	18	Conversion	33	Leptin	14
Gastroesophageal reflux disease	18	Gastrojejunostomy	33	Laparoscopic sleeve gastrectomy	14
Conversion	17	Revisional surgery	33	Reoperation	13
Laparoscopic Roux-en-y gastric bypass	17	Small bowel obstruction	31	Swedish adjustable gastric band	13
Excess weight loss	16	Glucagon-like peptide-1	31	Follow-up	13
Reflux	15	Diabetes mellitus	30	Ghrelin	13
Metabolic syndrome	15	Marginal ulcer	30	Body mass index	12
Endoscopy	15	Postoperative complications	29	Gastroplasty	12
Bleeding	15	Laparoscopic sleeve gastrectomy	28	Band slippage	12
Hypertension	14	Vitamin D	26	Laparoscopic surgery	12
Biliopancreatic diversion	14	Hypoglycemia	26	Duodenal switch	11
Laparoscopic surgery	13	Body composition	25	Laparoscopic gastric bypass	11

Table 4 (continued)

Sleeve gastrectomy		Gastric bypass		Gastric band	
Keyword	O	Keyword	O	Keyword	O
GERD	13	Anastomosis	24	Long-term results	11
Gastric emptying	13	Hypertension	23	Adolescent	11
Insulin resistance	12	Vertical banded gastroplasty	23	Excess weight loss	10

O: Occurrences

for South American countries, AGB publications were at the top in Argentina and Peru. Recently, developing countries have displayed an increase in the number of publications in the field of BS [8]. The present study showed that there were more SG publications in India and Turkey, and there were more RYGB publications in Brazil and China. SG publications were at the top in some other developing countries (especially Ukraine and Romania, and Chile). BS publications are known to be scarce in Africa [8]. This study found that publications from this region were mainly about SG.

Top publications in citation ranking were found to be related to the effects of the procedures on obesity and diabetes, some hormonal changes (especially ghrelin, glucagon like peptide-1), and complications. Particularly, the study entitled "FXR is a molecular target for the effects of vertical sleeve gastrectomy" written by Ryan Karen K et al. and published in the journal of *Nature* in 2014 was noteworthy. The study reports that metabolic activity of BS does not result from only the restrictive and malabsorptive effect. The study found a notable increase in enterohepatic circulation of total bile acids after SG and RYGB; it also reported that bile acids bind to FXR and contribute to the regulation of metabolic processes (beside their role in lipid digestion and absorption). Another important study was "Long-Term Mortality after Gastric Bypass Surgery" written by Adams Ted D et al. and published in *New England Journal of Medicine* in 2007. The study monitored patients who underwent RYGB operation for 7.1 years and compared the results with severely obese control group which was not administered surgical procedures. After RYGB, there was a significant decrease in long-term total mortality; particularly deaths from diabetes, heart disease, and cancer. However, in comparison to the control group, surgery group was reported to have higher rate of death from causes other than disease [32]. Adams Ted D et al. reported on the long-term effects of RYGB and explained that despite the changes in its popularity, it has remained to be the most commonly performed BS. Citation ranking indicated only four publications in 2010 and later, and all of them were about SG. This result is important in terms of explaining the popularity of SG in recent years.

An analysis of the most commonly used keywords in the abstracts of the SG publications in Fig. 7 indicates three main clusters. These are "weight loss," "metabolic activity," and "complications" (particularly gastroesophageal reflux and sleeve leaks" and "weight regain and revision." The most frequently used keywords in the abstracts of RYGB publications are shown in Fig. 8, which indicates four main clusters. These are respectively "effects on diabetes," "hormonal changes" (ghrelin, insulin, glucagon-like peptide-1), "complications (e.g., internal hernia, anemia, gallstone, stricture) and treatments", and finally "revision." An analysis of the most frequently used keywords in the AGB publication abstracts in Fig. 9 shows two main clusters. These are "comparisons with other operations" and "complications" (e.g., band erosion, band migration, and pouch dilatation). Keywords related to all three operations indicated that the history of BS could be summarized with "metabolic activity and complication" keywords. RYGB and SG publications generally indicate similar words. However, AGB publications seem to focus more on comparisons with other methods. The literature indicates that although RYGB and SG procedures are more disadvantageous in terms of perioperative risk in comparison to AGB, they are more effective for the solution to the weight loss and obesity-related comorbid disease [28, 33].

The most active authors in SG, RYGB, and AGB publications are Gagner M (64, 1.8%), Le Roux CW (83, 1.1%), and O'brien PE (50, 1.9%) respectively. The procedure in which all three authors were the top was also the most popular procedure in their country in terms of bibliometrics. Dr. Gagner (Canada) is reported to contribute to the field of minimally invasive surgery, especially the first description of laparoscopic SG [34]. Dr. Le Roux (Ireland) is known to be a metabolic medicine physician who is interested in obesity. He is particularly interested in the way BS works. Dr. O'brien from (Australia) is reported to be the world leader in laparoscopic AGB. In the early 1990s, he took part in the design and testing of the Lap-Band, and he was the first person to place Lap-Band in Australia in 1994 [35].

Journals in the field of surgery were found to be superior in the publications about all three surgical procedures. Distribution of non-surgical journals was similar for all three procedures, which is somewhat expected because the purpose of all bariatric procedures is the treatment of the diseases related to obesity. An analysis of the journals with highest

number of publications showed that *Obesity Surgery* was the most active journal in all three methods. The journal ranked second was *SOARD*. In many bibliometric studies, *Obesity Surgery* and *SOARD* (published in 1991 and 2005, respectively) are ranked at the top 2 in the number of both publications and citations [8, 10].

In our study, the procedure with the highest total *h* index was RYGB which was followed by SG and AGB. The *h* index can be defined as an effective single metric number for measuring quality and quantity together. This indicator can be applied explicitly to any group of articles [36, 37].

The present study has a number of limitations. Firstly, this study utilized the WoS database as it provides the most reliable service for publications and citations. All the journals indexed in this database had impact factors. Secondly, SG received its code in 2010; hence, we needed to use a generic code for "laparoscopic gastroplasty" in order to estimate the number of SG procedures, which may underestimate the exact number of procedures. Next, we searched the publications about the procedures in the article titles. This way, we aimed to focus specifically on that procedure. Finally, this study did not make a correlational analysis between the developmental indicators of the countries. It could be concluded that SG is bibliometrically more popular in developing counties; however, we can reach no judgment about this.

Conclusion

Bibliometric analysis results of this study showed that the USA was the top country in all three bariatric procedures. The most active authors were Gagner M (SG), Le Roux CW (RYGB), and O'brien PE (AGB). *Obesity Surgery* was the journal with most publications in all three methods. RYGB procedure was found to be at the top for 16 years in terms of the number of both publications and citations. While there was a dramatic proportional increase in the SG popularity especially between 2008 and 2016, there was a decrease in RYGB and AGB. While RYGB was the top procedure in terms of bibliometrics, the popular procedure was SG.

Compliance with Ethical Standards

Conflict of Interest Author 1 has nothing to disclose. Author 2 has nothing to disclose.

Ethical Approval Statement For this type of study, formal consent is not required.

Informed Consent Does not apply.

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