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Fecoflowmetric Analysis of Anorectal Motor Function in Postoperative Anal-Preserving Surgery Patients With Low Rectal Cancer Comparison With the Wexner Score and Anorectal Manometry

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The aim of this study was to elucidate whether fecoflowmetry (FFM) could evaluate more detailed evacuative function than anorectal manometry by comparing between FFM or anorectal manometric findings and the clinical questionnaires and the types of surgical procedure in the patients who received anal-preserving surgery. Fifty-three patients who underwent anal-preserving surgery for low rectal cancer were enrolled. The relationships between FFM or the manometric findings and the clinical questionnaires and the types of procedure of anal-preserving surgery were evaluated. There were significant differences between FFM markers and the clinical questionnaire and the types of the surgical procedure, whereas no significant relationship was observed between the manometric findings and the clinical questionnaire and the types of the surgical procedure. FFM might be feasible and useful for the objective assessment of evacuative function and may be superior to manometry for patients undergoing anal-preserving surgery.

Key words: Anorectal manometry – Anal-preserving surgery – Fecoflowmetry – Incontinence – Rectal cancer

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Sphincter preservation has been one of the key issues of rectal cancer surgery. Low anterior resection (LAR)[1] and internal and external sphincter resection (ISR and ESR) are anal-preserving surgeries.[2,3] The aim of these procedures is to restore the normal process of defecation, along with its function, and to improve the quality of life of patients by avoiding permanent colostomy. However, anal-preserving surgery is often associated with evacuative dysfunction and various degrees of incontinence.[4–7]

Most studies that have assessed the evacuation function have used clinical questionnaires, which are subjective and may vary according to the patient perception.[7] There are many factors that can affect the evacuative function, such as the stool consistency, rectal capacity, anal sphincters, pelvic floor muscles, and intra-abdominal pressure. Although manometry with or without the clinical score has also commonly been used, fecoflowmetry (FFM) has been reported to be more accurate and useful for assessing the postoperative anorectal motor function.[8–13] FFM was first introduced by Shafik and is a dynamic method for examining the anorectal motor activity that simulates the natural act of defecation.[14] Some studies have shown its usefulness in postoperative patients with anorectal disease,[8–11] but only a few studies have been performed to examine the evacuative function following anal-preserving surgery.[12,13] The aim of this study was to evaluate the evacuative function in the postoperative period following anal-preserving surgery in patients with low rectal cancer using FFM, and to compare the results with the Wexner score and anorectal manometry.[15]

Patients and Methods

Patients

Between April 2001 and October 2011, 433 patients underwent anal-preserving surgery for low rectal cancer in our hospital. In consequence, 53 patients (35 males, 18 females) were enrolled in the study. Patients who had cancer recurrence were excluded from the study. Breakdown of the remaining 380 patients concerning survival were as follows: alive, 336; dead, 44. Furthermore, breakdown of the 336 survivors were as follows: no recurrence, 300; recurrence, 36 (local, 5; distant metastasis, 31). They ranged in age from 29 to 82 years, with a mean age of 60 years. The anal-preserving surgeries were carried out as follows: LAR in 21 patients, ultralow anterior resection only (ULAR) in 9 patients, ULAR with ISR in 15 patients, and ULAR with ESR in 8 patients.

Written informed consent was obtained from all patients, and the study was approved by the ethics committee for human subjects at Kurume University School of Medicine (Approval No. 09315). The assessment of the anorectal motor function was performed using a subjective questionnaire, FFM, and manometry, and these examinations were done at least 3 months after closure of the ileostomy.

Clinical assessment of the anorectal motor function

The evacuative function was evaluated by surveying the patients using a set questionnaire about soiling, the frequency of defecation (5 or more evacuations every 2 to 3 days), urgency (incapacity to wait for more than 15 minutes), and pad wearing. Incontinence was assessed by using the continence score of Wexner[15] (range, 0–20; 0 = perfect continence; 20 = major incontinence).

Procedure for manometry

Before starting fecoflowmetry, conventional anorectal manometry was performed. The patients were given a 50% glycerin enema of 120 mL to evacuate their bowels before the examination. Anorectal manometry was performed using a single-channel pressure sensor, the GMMS 100/ACP 101 (Star Medical Co, Tokyo, Japan). The measured parameters were the maximum resting pressure (MRP) and maximum squeezing pressure (MSP).

Fecoflowmetry measurement

Fecoflowmetry was performed using a scale-redesigned uroflowmeter, which could record a maximum fecal flow rate up to 200 mL/s (Takei Medical & Optical Co, Tokyo, Japan), consisting of a weight transducer, an amplifier, and a chart recorder according to the previous report.[8–13] To imitate stool movement, a normal saline enema was instilled at 37°C with a volume of 1000 mL under gravity through a 6-Fr catheter, in the left lateral position, while the anorectal pressure was monitored. When the urge to defecate could no longer be suppressed or major leakage of the imitated stool, or severe abdominal pain developed, the normal saline instillation was discontinued. The patient was asked to retain the enema fluid for as long as possible. When the urge to defecate could no longer be suppressed, the patient sat on the seat of the FFM

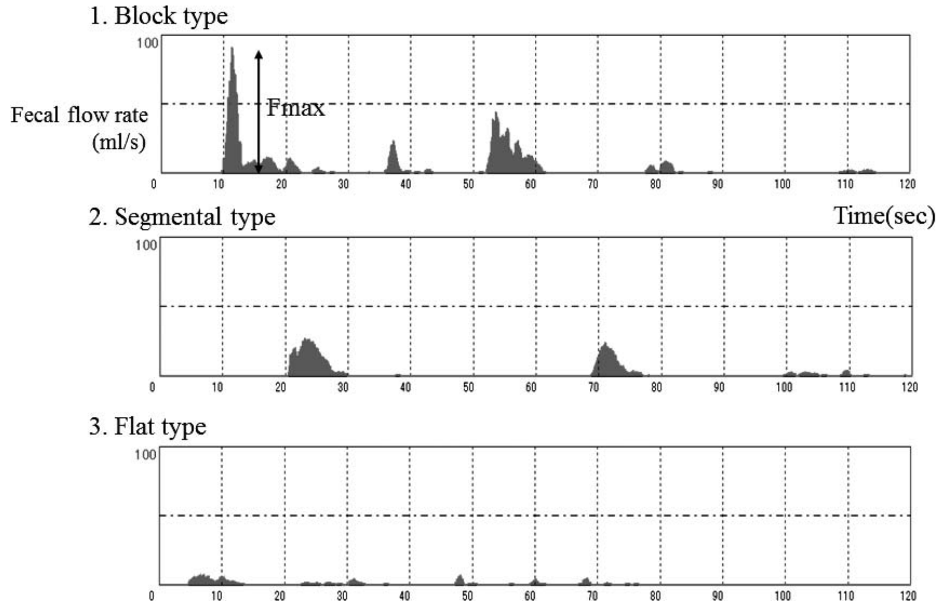

Fig. 1 The fecoflow patterns. The x-axis represents the time (seconds) and the y-axis represents the fecal flow rate (milliliters per second). Fmax (milliliters per second). (1) block type: Fmax > 45 mL/s, (2) segmental type: 15 mL/s < Fmax < 45 mL/s, (3) flat type: Fmax < 15 mL/s.

and was left alone while defecating to obviate any psychologic inhibitory factors.[8,9] The tolerance volume [TV (mL)] of the normal saline solution in the rectum, evacuative volume [EV (mL)], and maximum fecal stream flow rate [Fmax (mL/s)] in the FFM were measured according to Yagi's method.[8,9] After these measurements were performed, the evacuative rate [ER: (EV/TV) $\times$ 100 (%)] was calculated. The fecoflow pattern (FFP) was classified according to Yagi's report.[8] The curve of the "block type" showed a hump shape without segmentation, and the Fmax was above 45 mL/s. The curve of the "segmental type" showed some segmental areas, and the Fmax was above 15 mL/s. The curve of the "flat type" was a low peak flow wave, and the Fmax was below 15 mL/s (Fig. 1).

Comparisons of FFM markers and manometric findings from the view point of the clinical assessment

The relationships between the questionnaire described above and FFM markers, including the manometric results, were evaluated to determine the clinical usefulness of FFM. The questionnaire items assessed were the following: soiling (positive or negative), frequency of defecation (FD-positive, >5 or 5 evacuations every 2 or 3 days; FD-negative, <5 evacuations every 2 or 3 days), urgency (good, able to wait more than 15 minutes; poor, unable to wait 15 minutes), and pad wearing (positive or negative).

Comparisons of FFM markers and manometric findings from the view points of ISR and ESR

The relationships between the surgical procedures and FFM markers, including the manometric results, were also evaluated to assess the clinical usefulness of FFM. To avoid the operative effect to anorectal motor function, FFM markers were compared between LAR + ULAR (n = 14) and ISR + ESR (n = 15) who received the closure of ileostomy at least one year before the present study.

Statistical analysis

The statistical analysis was performed using the JMP Statistical Software Program, Version 10 (SAS Institute, Cary, North Carolina). The Wilcoxon *t* test, χ^2 test, Fisher's exact test, Kruskal-Wallis test, and Tukey-Kramer HSD test were used. A value of $P <$ 0.05 was considered to be statistically significant.

Results

The FFPs were grossly classified into 3 types, as previously reported: the block type, segmental type, and flat type (Fig. 1). In the FFM of the soiling-

Table 1. Comparison between the fecoflowmetry and manometry findings about soiling[a]

	Soiling-positive group (n = 32)	Soiling-negative group (n = 21)	*P* value
FFM			
TV, mL	379.4 ± 243.1	734.2 ± 290.2	0.0001*
Fmax, mL/s	25. 5 ± 29.5	78. 3 ± 56.0	0.0002*
ER, %	42.9 ± 30.8	66. 5 ± 28.8	0.0066*
FFP			
Block	4	14	0.0001*
Segmental	12	5	
Flat	16	2	
Manometry			
MRP, mmHg	38.6 ± 19.1	50.4 ± 24.5	0.0777
MSP, mmHg	176.6 ± 77.0	206.2 ± 94.6	0.4396

[a]Values are the mean ± SD.
**P* < 0.05.

positive group (n = 32), the TV, Fmax, and ER were 379.4 ± 243.1 mL, 25.5 ± 29.5 mL/s, and 42.9% ± 30.8%, respectively. In the FFM of the soiling-negative group (n = 21), the TV, Fmax, and ER were 734.2 ± 290.2 mL, 78.3 ± 56.0 mL/s, and 66.5% ± 28.8%, respectively. There were significant differences in the TV, Fmax, and ER between the soiling-positive and -negative groups (*P* = 0.0001, *P* = 0.0002, and *P* = 0.0066, respectively). In the manometric analysis of the soiling-positive group (n = 32), the MRP and MSP were 38.6 ± 19.1 mmHg and 176.6 ± 77.0 mmHg, respectively. In the manometric analysis of the soiling-negative group (n = 21), the MRP and MSP were 50.4 ± 24.5 mmHg and 206.2 ± 94.6 mmHg, respectively. There were no significant differences in the MRP and MSP between the soiling-positive and -negative groups (*P* = 0.0777 and *P* = 0.4396, respectively). There was a close relationship between the FFPs and the presence of soiling (χ^2 value = 17.81, *P* = 0.0001) (Table 1).

In the FFM of the FD-positive group (n = 13), the TV, Fmax, and ER were 255.8 ± 130.7 mL, 11.1 ± 11.4 mL/s, and 25.1% ± 24.6%, respectively. In the FFM of the FD-negative group (n = 40), the TV, Fmax, and ER were 605.9 ± 308.3 mL, 57.4 ± 50.8 mL/s, and 61.1% ± 29.1%, respectively. There were significant differences in the TV, Fmax, and ER between the FD-positive and FD-negative groups (*P* = 0.0005, *P* = 0.0002, and *P* = 0.0004, respectively). In the manometric analysis of the FD-positive group (n = 13), the MRP and MSP were 40.1 ± 21.9 mmHg and 191.5 ± 88.6 mmHg, respectively. In the manometric analysis of the FD-negative group (n = 40), the MRP and MSP were 44.3 ± 22.2 mmHg and 187.2 ± 84.7 mmHg, respectively. There were no significant differences in the MRP and MSP between the soiling-positive and -negative groups (*P* = 0.6418 and *P* = 0.7021, respectively). There was a close relationship between the FFPs and the presence of FD (χ^2 value = 15.646, *P* = 0.0004; Table 2).

In the FFM of the poor urgency group (<15 minutes; n = 21), the TV, Fmax, and ER were 287.6 ± 203.6 mL, 14.2 ± 12.8 mL/s, and 36.2% ± 29.8%, respectively. In the FFM of the good urgency group (>15 minutes; n = 32), the TV, Fmax, and ER were 672.5 ± 278.6 mL, 67.2 ± 52.4 mL/s, and 62.8% ± 29.2%, respectively. There were significant differences in the TV, Fmax, and ER between the poor and good urgency groups (*P* < 0.0001, *P* < 0.0001, and *P* < 0.0028, respectively). In the manometric analysis of the poor urgency group (n = 21), the MRP and MSP were 34.4 ± 18.3 mmHg and 154.2 ± 64.4 mmHg, respectively. In the manometric analysis of good urgency group (n = 32), the MRP and MSP were 49.1 ± 22.4 mmHg and 210.7 ± 90.0 mmHg, respectively. There were significant differences in the MRP and MSP between the poor and good urgency groups (*P* = 0.0185 and *P* = 0.0291, respectively). There was a close relationship between the FFPs and the degree of urgency (χ^2 value = 18.576, *P* < 0.0001; Table 3).

In the FFM of the pad-wearing positive group (n = 31), the TV, Fmax, and ER were 382.6 ± 240.0 mL, 25.3 ± 27.1 mL/s, and 43.1% ± 30.8%, respectively. In the FFM of the pad-wearing negative group (n = 22), the TV, Fmax, and ER were 713.6 ± 306.7 mL, 76.1 ± 57.6 mL/s, and 65.2% ± 29.7%, respectively. There were significant differences in the TV, Fmax, and ER between the pad-wearing positive group and the pad-wearing negative group (*P* = 0.0003, *P* = 0.0002, and *P* = 0.0101, respectively). In the manometric analysis of the pad-wearing positive

Table 2. Comparison between the fecoflowmetry and manometry findings regarding FD[a]

	FD-positive (n = 13)	FD-negative (n = 40)	*P* value
Fecoflowmetry			
TV, mL	255.8 ± 130.7	605.9 ± 308.3	0.0005*
Fmax, mL/s	11.1 ± 11.4	57.4 ± 50.8	0.0002*
ER, %	25.1 ± 24.6	61.1 ± 29.1	0.0004*
FFP			
Block	0	18	0.0004*
Segmental	3	14	
Flat	10	8	
Manometry			
MRP, mmHg	40.1 ± 21.9	44.3 ± 22.2	0.6418
MSP, mmHg	191.5 ± 88.6	187.2 ± 84.7	0.7021

[a]FD-positive, >5 times every 2 or 3 days; FD-negative, <4 times every 2 or 3 days. Values are the mean ± SD.
*$P < 0.05$.

group (n = 36), the MRP and MSP were 37.3 ± 18.5 mmHg and 174.9 ± 87.5 mmHg, respectively. In the manometric analysis of the pad-wearing negative group (n = 22), the MRP and MSP were 51.8 ± 24.0 mmHg and 207.3 ± 79.0 mmHg, respectively. There was a significant difference in the MRP between the pad-wearing positive and pad-wearing negative groups ($P = 0.0264$). There was no significant difference in the MSP between the pad-wearing positive and pad-wearing negative groups ($P = 0.1317$). There was a close relationship between FFPs and pad wearing (χ^2 value = 13.845, $P = 0.0010$; Table 4).

The averaged Wexner scores of block, segmental, and flat types were 3.28 ± 2.13, 8.12 ± 5.00, and 9.94 ± 3.02, respectively. There were significant differences in the Wexner scores among the 3 FFP patterns ($P < 0.001$, Kruskal-Wallis test). There were significant differences in the Wexner score between the block-type and segmental-type scores, and between the block-type and flat-type scores, respectively [both $P < 0.001$, Tukey-Kramer honestly significant difference (HSD) test; Fig. 2].

There were no significant differences in the patient backgrounds between the LAR + ULAR group (n = 14) and the ISR + ESR group (n = 15) (Table 5). There was no close relationship between the soiling and the surgical procedures (χ^2 value = 2.773, $P = 0.1394$). However, there were close relationships between the FD and surgical procedures (χ^2 value = 7.061, $P = 0.0169$), and between the urgency and surgical procedures (χ^2 value = 10.311, $P = 0.0022$). There was also a close relationship between the pad-wearing positive and the procedure (χ^2 value = 7.744, $P = 0.0092$), but no

Table 3. Comparison between the fecoflowmetry and manometry findings for urgency[a]

	Urgency <15 min (n = 21)	Urgency >15 min (n = 32)	*P* value
Fecoflowmetry			
TV, mL	287.6 ± 203.6	672.5 ± 278.6	<0.0001*
Fmax, mL/s	14.2 ± 12.8	67.2 ± 52.4	<0.0001*
ER, %	36.2 ± 29.8	62.8 ± 29.2	0.0028*
FFP			
Block	0	18	<0.0001*
Segmental	9	8	
Flat	12	6	
Manometry			
MRP, mmHg	34.4 ± 18.3	49.1 ± 22.4	0.0185*
MSP, mmHg	154.2 ± 64.4	210.7 ± 90.0	0.0291*

[a]Values are the mean ± SD.
*$P < 0.05$.

Table 4. Comparison between the fecoflowmetry and manometry findings regarding pad wearing[a]

	Pad-wearing positive group (n = 31)	Pad-wearing negative group (n = 22)	*P* value
FFM			
TV, mL	382.6 ± 240.0	713.6 ± 306.7	0.0003*
Fmax, mL/s	25.3 ± 27.1	76.1 ± 57.6	0.0002*
ER, %	43.1 ± 30.8	65.2 ± 29.7	0.0101*
FFP			
Block	5	13	0.0010*
Segmental	10	7	
Flat	16	2	
Manometry			
MRP, mmHg	37.3 ± 18.5	51.8 ± 24.0	0.0264*
MSP, mmHg	174.9 ± 87.5	207.3 ± 79.0	0.1317

[a]Values are the mean ± SD.
*$P < 0.05$.

relationship between the Wexner score and procedures performed ($P = 0.1007$) (Table 5).

In the FFM of the LAR + ULAR group (n = 14), the TV, Fmax, and ER were 818.2 ± 208.2 mL, 85.4 ± 43.9 mL/s, and 75.5% ± 23.2%, respectively. In the FFM of the ISR + ESR group (n = 15), the TV, Fmax, and ER were 424.7 ± 280.6 mL, 25.5 ± 22.6 mL/s, and 52.5% ± 28.6%, respectively. There were significant differences in the TV, Fmax, and ER between the LAR + ULAR group and ISR + ESR group ($P = 0.0009$, $P = 0.0006$, and $P = 0.0307$, respectively). In the manometric analysis of the LAR + ULAR group (n = 14), the MRP and MSP were 49.5 ± 26.3 mmHg and 188.1 ± 86.5 mmHg, respectively. In the manometric analysis of the ISR + ESR group (n = 15), the MRP and MSP were 45.4 ± 21.0 mmHg and 178.1 ± 81.3 mmHg, respectively. There were no significant differences in the MRP and MSP between the LAR + ULAR and ISR + ESR groups ($P = 0.8272$ and $P = 0.7269$, respectively). There was a close relationship between the FFPs and surgical procedures (χ^2 value = 10.812, $P = 0.0045$) (Table 5).

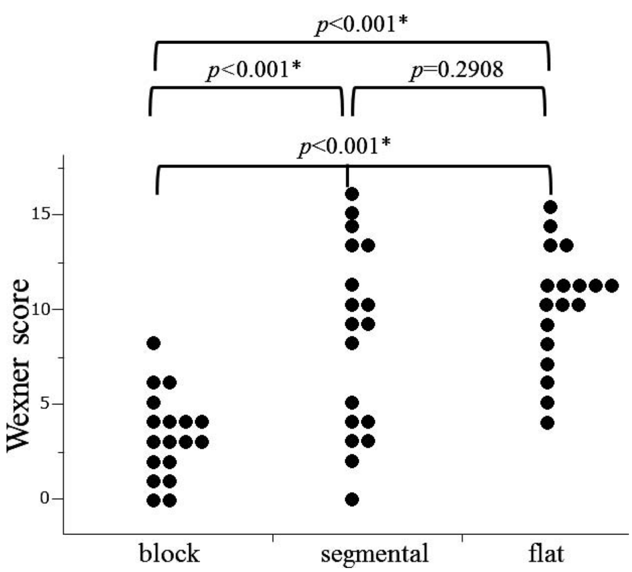

Fig. 2 The relationship between the FFP and Wexner score. There were significant differences in the Wexner scores among the 3 FFP patterns ($P < 0.001$, Kruskal-Wallis test). There were significant differences in the Wexner score between the block type and segmental type, and between the block-type and flat-type scores, respectively (both $P < 0.001$, Tukey-Kramer HSD test).

Discussion

The type of surgical treatment for low rectal cancer is generally determined by the location and degree of tumor invasion. The development of surgical devices has enabled anal preservation during many surgeries. Careful resection is required for rectal cancers located just above the anus in order to secure safer distal and radial margins in the anal canal. Abdominoperineal resection (APR) is usually applied in cases where anal preservation is not attempted. Surgical treatment for lower rectal cancer must provide both curability and preservation of the anorectal motor function. However, an ultimate anal-preserving technique with sphincter-muscle resection, intersphincteric resection (ISR) as defined by Schiessel *et al*,[2] can be performed for these cancers and has become widely applied around the world.[3,16,17] This procedure is initiated to avoid permanent colostomy for very low rectal cancers, which might previously have required APR. However, the patients with low rectal cancer treated by anal-preserving surgery often have disorders in

Table 5. Comparison between the fecoflowmetry and manometry findings for the different surgical procedures[a]

	LAR + ULAR (n = 14)	ISR + ESR (n = 15)	*P* value
Age, y	57.8 ± 17.1	59.5 ± 10.7	0.7817
Sex			
Male	8	9	1.0000
Female	6	6	
Duration after stoma closure, mo	24.8 ± 15.9	32.3 ± 12.2	0.0696
Soiling			
Positive	6	11	0.1394
Negative	8	4	
FD			
Positive	0	6	0.0169*
Negative	14	9	
Urgency			
>15 min	14	7	0.0022*
<15 min	0	8	
Pad wearing			
Positive	4	12	0.0092*
Negative	10	9	
Wexner score	4.8 ± 4.9	7.1 ± 3.7	0.1007
Fecoflowmetry			
TV, mL	818.2 ± 208.2	424.7 ± 280.6	0.0009*
Fmax, mL/s	85.4 ± 43.9	25.5 ± 22.6	0.0006*
ER, %	75.5 ± 23.2	52.5 ± 28.6	0.0307*
FFP			
Block	10	2	0.0045*
Segmental	3	6	
Flat	1	7	
Manometry			
MRP, mmHg	49.5 ± 26.3	45.4 ± 21.0	0.8272
MSP, mmHg	188.1 ± 86.5	178.1 ± 81.3	0.7269

[a]Values are the mean ± SD.
*$P < 0.05$.

stool evacuation and decreased continence for gas and liquid stool, with increased stool frequency.[18–20] Postoperative patients often accept a degree of incontinence, so they can avoid a permanent stoma. Therefore, various degrees of evacuative dysfunction can be seen following anal-preserving surgery for low rectal cancers.

It is not easy to objectively evaluate the anorectal motor function, including the evacuative function. There are several examinations that can be performed for anorectal function, such as the clinical score, manometry, defecography, and electromyography.[6,21–23] However, it is difficult to conclude whether these examinations provide accurate results. Defecation is the sum of the functions of all mechanisms of anorectal evacuation. Conventional functional evaluations do not necessarily show good correlations between the investigative results and symptoms. Defecational symptoms frequently do not often correlate with the results of these examinations, even if the manometric study is performed in the postoperative patients a longer time after the surgery, giving time for their anorectal motor function to improve.

FFM was first introduced by Shafik *et al* to assess defecational disorders in adults.[24] Shafik *et al* reported that it was a useful method to evaluate the objective defecatory function in adult patients. There have been a few reports describing the use of FFM in the pediatric surgical field[8–11] as well as in the adult surgical field.[12,13]

The present study attempted to evaluate the postoperative anorectal motor function using FFM after anal-preserving surgery, and we compared the results with those obtained using different evaluations of the evacuative function, including the clinical score and manometry. FFM simulates the act of defecation and is carried out under conditions as close to natural defecation as possible. It provides clinically useful information and imitates diarrheic stool using saline, which allows the continence to be evaluated. The fecal flow rate is the product of the rectal detrusor action against the outlet resistance, including the rectal contraction and intra-abdominal pressure. This allows for a calculation of the defecated volume that passes per second and provides quantitative as well as qualitative data concerning defecation. There are 3 FFPs, and the typing of the FFP is an objective parameter of the anorectal motor function that can be accurately assessed. Patients with good continence usually show a characteristic block-type flow curve in FFM. FFM seemed to be a better technique for assessing the evacuation function compared with manometry, and it also had a better correlation with the clinical score compared with manometry. The TV and Fmax showed a statistically significant relationship, and the FFP also had a significant relationship to the TR >70% or ER >50%, which was statistically regarded as the cutoff for fecal continence in postoperative patients with anorectal malformation.[8] This block-type FFP was found in 18 patients, following anal-preserving surgery, who seemed to have good overall continence, which was significantly associated with decreased soiling, FD, urgency, and pad wearing. However, the manometry findings did not show any statistical significance with regard to these parameters.

The Wexner score is a convenient score to use in the clinical setting and is usually used in the postoperative patients treated for low rectal cancer. In this series, there was a significant relationship between the Wexner score and FFM findings. There were significant differences between surgical procedures with and without anal-sphincter resection in the constituent symptoms of the Wexner score. However, there was no significant difference between the above procedures in the Wexner score. Furthermore, there were significant differences in all the parameters of FFM (Table 5). Therefore, FFM was relatively useful for providing a quantitative and comprehensive evaluation of the anorectal motor function compared with the Wexner score and manometry in the postoperative patients who underwent anal-preserving surgery. Measurement of FFM was relatively easy. Therefore, it is an acceptable evaluation for postoperative patients—it is a relatively noninvasive simulation of defecation and the dynamic state of the defecation is easy to explain to patients. FFM is applicable not only in evaluating the intra-individual changes before and after anorectal surgery but also in assessing the effects of medical treatments and biofeedback therapy in the near future.

In conclusion, FFM might be feasible and useful as an objective and comprehensive assessment of the evacuative function and appears to be superior to manometry when used in patients who have undergone anal-preserving surgery.

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