Use of endoscopic distal attachment cap to enhance image stabilization in probe-based confocal laser endomicroscopy in colorectal lesions*

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Background and study aims: Colorectal cancer can be prevented through the use of colonoscopy with polypectomy. Most colon polyps are benign or low grade adenomas. However, currently all lesions need histopathologic analysis, which increases diagnostic costs and delays the final diagnosis. Confocal laser endomicroscopy (CLE) is a new technology that enables real-time endomicroscopy. However, there are challenges to maintaining a stable image with currently available systems. We conducted a small study to obtain a preliminary assessment of whether the use of an endoscopic distal attachment cap may enhance image quality of CLE in comparison with images obtained with free-hand acquisition.

Patients and methods: Forty outpatients underwent colonoscopy for evaluation of colon polyps in a single academic medical center. Patients were assigned randomly to 1 of 2 study arms on the basis of whether an endoscopic distal attachment cap was used (n = 21, Cap Used) or not used (n = 19, No Cap) in the procedure. The quality of confocal images and probe stabilization was summarized.

Results: A total of 81 polyps were identified. The proportion of polyps with images of high quality was 74 % (28/38) in the Cap Used group and 79 % (30/38) in the No Cap arm. Image stability was also similar with and without a cap. Diagnostic accuracy was estimated to be slightly higher in the Cap Used group for probe-based confocal laser endomicroscopy (pCLE; 78 % vs 70 %). This was also true for white-light and narrow-band imaging.

Conclusions: This preliminary study did not yield any evidence to support that the use of an endoscopic distal attachment cap improves the quality of images obtained during CLE.

Introduction

Confocal laser endomicroscopy (CLE) has the potential to allow in vivo endomicroscopy and, thus, avoid the need to resect nonneoplastic polyps or to resect and discard small, low grade adenomas when a high-confidence, accurate diagnosis is made. Guidelines for this strategy have been outlined by the American Society for Gastrointestinal Endoscopy, among other resources [1]. Because of the extreme (1000-fold) magnification of both endoscopic confocal laser endomicroscopy (eCLE) and probe-based confocal laser endomicroscopy (pCLE) systems, maintaining a stable image is challenging.

The incidence of colorectal cancer (CRC) and CRC-related deaths can be reduced by early detection with methods such as colonoscopy with polypectomy [2]. Currently, more than one-third of resected polyps are nonneoplastic, and greater than 90 % of neoplastic polyps are low grade tubular adenomas [3]. The cost of histopathologic confirmation of these is substantial, with more than 14 million colonoscopies performed annually in the United States [4]. Screening for CRC with colonoscopy is effective, safe, and widely used in the United States. Despite these advantages, the reliance on biopsy or polypectomy with ex vivo histopathologic examination remains a major limitation because of the increased risk to the patient associated with polypectomy of nonneoplastic lesions, overall cost, and delay in the final diagnosis.

In this study, we evaluated an image-enhancement technology, CLE, which enables in vivo histopathologic examination with mucosal analysis at the cellular level. This is particularly important for evaluating different types of polyps. Real-time assessment is possible through a high-resolution technique, which provides a 1000-fold magnifica-

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	No Cap (n = 19)	Cap Used (n = 21)
Age at procedure, y	64 (47, 57, 75, 85)	62 (48, 53, 76, 87)
Sex, male, no. (%)	12 (63)	11 (52)
Race, no. (%)		
White	16 (84)	18 (86)
African American	2 (11)	1 (5)
Hispanic	1 (5)	2 (10)
Patient history of CRC or adenoma, no. (%)	13 (68)	14 (70)
Family history of CRC, no. (%)	6 (32)	5 (28)
Indication for procedure, no. (%)		
Screening	1 (5)	0 (0)
Surveillance average prior polyps	1 (5)	2 (10)
EMR	1 (5)	3 (14)
EMR follow-up	14 (74)	15 (71)
Other (polypectomy, transanal resection, poor procedure preparation)	2 (11)	1 (5)

Table 1 Characteristics of 40 patients undergoing colonoscopy (January 10 – November 5, 2012) with or without an endoscopic distal attachment cap.

No Cap, colonoscopy performed without an endoscopic distal attachment cap; Cap Used, colonoscopy performed with an endoscopic distal attachment cap; CRC, colorectal cancer; EMR, endoscopic mucosal resection.
The sample median (minimum, 25th percentile; maximum, 75th percentile) is given for continuous variables. Information was unavailable for some patients regarding patient history of CRC or adenoma (n = 1, Cap Used) and family history of CRC (n = 3, Cap Used) and, therefore, could not been included in the summaries. Percentages for race in the Cap Used group sum to 101 % because of rounding.

tion [5] and yields in vivo analysis of cellular components and vascular distribution. Two different types of CLE systems are currently available. One is integrated to the endoscope (eCLE) and developed by Pentax (Tokyo, Japan).The other is probe based (pCLE), which consists of a through-the-scope system from Mauna Kea Technologies (Paris, France) [6].

The primary aim of this study was to obtain a preliminary assessment of whether the use of an endoscopic distal attachment cap may enhance probe stabilization in comparison with free-hand image acquisition, with image quality as the primary outcome measure. Image quality was assessed by conducting an offline blinded review of images. Our secondary aims were to explore whether polyp size may be important in the comparison of image quality and probe stability. We also examined the confidence level and duration of, as well as compared images obtained with, pCLE, white-light (WL), and narrow-band (NB) imaging methods. Finally, we measured biopsy time, colonoscope insertion time, and colonoscope withdrawal time with or without the use of a cap. Comparison of confocal diagnosis was based on the Miami classification system [7] with regard to the histopathologic findings and distinction of neoplastic polyps between the 2 study groups.

Patients/Materials and methods

The study was approved by the Institutional Review Board of the Mayo Clinic (Jacksonville, Florida, USA) and was registered at clinicaltrials.gov (NCT01515514; Confocal Endomicroscopy for GI Neoplasia Study).

A total of 40 outpatients, who underwent planned colonoscopy (January 10 – November 5, 2012) for evaluation of colon polyps, were included in the study. Exclusion criteria were known polyposis syndromes, inflammatory bowel disease, allergy to fluorescein, or refusal to provide informed consent.

Just before the procedure was performed, each patient was assigned, through a computerized randomization system, to 1 of 2 study arms on the basis of whether an endoscopic distal attachment cap (4 mm, D-201-16403; Olympus America, Center Valley, Pennsylvania, USA) was used (n = 21, Cap Used) or not used (n = 19, No Cap). Standard colonoscopic imaging was performed first, followed by injection of 5 mL of 10 % fluorescein (Akorn Pharmaceuticals, Lake Forest, Illinois, USA). One minute after fluorescein injection, pCLE imaging commenced and was continued until images of adequate quality, as defined by in-focus, stable imaging of colonic epithelium, were obtained from representative areas of the polyps. The probe was maintained 3 to 4 mm distal to the endoscope tip. When a cap was used, the cap was placed in direct contact with the colon wall and over the polyp to stabilize the image. Confocal imaging was subsequently performed. To standardize imaging relative to the fluorescein timing, no more than 3 lesions per patient were imaged, which was limited to the first 8 minutes after injection. All pCLE images were captured by the principal investigator of the study (M. B. W.), who has extensive experience with pCLE (> 500 pCLE cases). The pCLE manipulation, including probe management and capture of images, was completed by either a research fellow, program coordinator, or visiting physician, all of whom had prior training. After imaging, each polyp was removed with snare or biopsy forceps and evaluated by using standard histopathologic methods.

Because the presence of a cap would not allow blinding during the study, all images on the Cellvizio system (Mauna Kea Technologies) video were recorded. Each video was reviewed offline by an expert (M. B. W.), who was blinded to the cap use and image acquisition method. Technical quality of each video sequence was scored subjectively by using the results of the histopathologic findings as a reference standard (1 – 5 scale: 1, worst image quality; 3, acceptable image quality; 5, image quality equal to that of histopathologic findings). Scoring of image stability and motion artifact was also recorded by using a similar 1 – 5 scale (1, worst image stability; 3, acceptable image stability; 5, stability equal to that of histopathologic findings).

Statistical considerations

- The study was designed as a preliminary and pilot study, with the aim of gaining estimates of accuracy of diagnosis, with the results intended to guide the design of a potentially larger and powered study. The study was not powered to definitively assess differences in the techniques. Thus, tests of statistical inference were not performed, because results can be misleading in small studies.
- We planned to enroll 40 patients, with the expectation that colonoscopy in these patients would yield approximately 60

	No Cap (n = 41)	Cap Used (n = 40)
Image quality, no. (%)		
1 = worst	0 (0)	0 (0)
2	1 (3)	1 (3)
3 = acceptable	7 (18)	9 (24)
4	18 (47)	17 (45)
5 = equal to histopathologic findings	12 (32)	11 (29)
4 or 5 = high quality	30 (79)	28 (74)
Image stability, no. (%)		
1 = worst	2 (5)	4 (10)
2	8 (20)	4 (10)
3 = acceptable	7 (18)	14 (35)
4	10 (25)	11 (28)
5 = equal to histopathologic findings	13 (33)	7 (18)
4 or 5 = high quality	23 (58)	18 (45)
Percent acceptable image	70 (10, 43, 90, 95)	60 (10, 50, 70, 95)
Confidence level, no. (%)		
Low	13 (33)	6 (16)
High	27 (68)	32 (84)
Diagnosis, no. (%)		
Hyperplastic/normal tissue	26 (63)	27 (68)
Adenoma		
Low grade	11 (27)	9 (23)
High grade	1 (2)	4 (10)
Traditional serrated	3 (7)	0 (0)

Table 2 Offline probe-based confocal laser endomicroscopy (pCLE) image interpretation of 81 polyps resected from 40 patients undergoing colonoscopy (January 10 – November 5, 2012) with or without an endoscopic distal attachment cap.

No Cap, colonoscopy performed without an endoscopic distal attachment cap; Cap Used, colonoscopy performed with an endoscopic distal attachment cap.
The sample median (minimum, 25th percentile; maximum, 75th percentile) is given for percent acceptable image. Information for some polyps identified was unavailable regarding image quality (n = 3, No Cap; n = 2, Cap Used), image stability (n = 1, No Cap), percent acceptable image (n = 1, No Cap), and confidence level (n = 1, No Cap; n = 2, Cap Used) and, therefore, could not been included in the summaries. Percentage sums that do not equal 100 % are due to rounding.

	Overall polyps identified (N = 81)	No Cap (n = 41)	Cap Used (n = 40)
Polyp size, mm, no. (%)			
1 – 4	22 (27)	13 (32)	9 (23)
5 – 8	16 (20)	9 (22)	7 (18)
10	14 (17)	9 (22)	5 (13)
≥ 15	13 (16)	3 (7)	10 (25)
No size recorded	16 (20)	7 (17)	9 (23)
1 – 9	38 (47)	22 (54)	16 (40)
≥ 10	27 (33)	12 (29)	15 (38)
No size recorded	16 (20)	7 (17)	9 (23)
Prior EMR site, no. (%)	24 (30)	13 (32)	11 (28)
Site, no. (%)			
Cecum	14 (17)	8 (20)	6 (15)
Ascending colon	20 (25)	8 (20)	12 (30)
Hepatic flexure	2 (2)	1 (2)	1 (3)
Transverse colon	11 (14)	7 (17)	4 (10)
Splenic flexure	1 (1)	0 (0)	1 (3)
Descending colon	3 (4)	1 (2)	2 (5)
Sigmoid colon	13 (16)	8 (20)	5 (13)
Rectum	17 (21)	8 (20)	9 (23)
Histopathologic findings, no. (%)			
Hyperplastic tissue	17 (22)	10 (27)	7 (18)
Other non-neoplasia	27 (35)	10 (27)	17 (43)
Adenoma	27 (35)	16 (43)	11 (28)
Traditional serrated adenoma	3 (4)	1 (3)	2 (5)
Tubulovillous adenoma	3 (4)	0 (0)	3 (8)

Table 3 Characteristics of 81 polyps resected from 40 patients undergoing colonoscopy (January 10 – November 5, 2012) with or without an endoscopic distal attachment cap.

No Cap, colonoscopy performed without an endoscopic distal attachment cap; Cap Used, colonoscopy performed with an endoscopic distal attachment cap; EMR, endoscopic mucosal resection.
Information was unavailable for some polyps identified regarding histopathologic findings (n = 4, No Cap) and, therefore, could not been included in the summaries. No polyps were 9 mm. No polyps were in the range of 11 to 14 mm. Percentage sums that do not equal 100 % are due to rounding.

Table 4 Diagnostic accuracy, with the use of white-light (WL), narrow-band (NB), and probe-based confocal laser endomicroscopy (pCLE) offline and online imaging methods, for 81 (77 evaluable) polyps resected from 40 patients undergoing colonoscopy (January 10 – November 5, 2012) with or without an endoscopic distal attachment cap.

Imaging diagnosis	No Cap			Cap Used		
	Normal tissue (n = 20)	Adenoma (n = 17)	Accuracy, no. (%) (n = 37)	Normal tissue (n = 24)	Adenoma (n = 16)	Accuracy, no. (%) (n = 40)
WL			26/37 (70)			32/39 (82)
Hyperplastic/normal tissue	14	5		18	2	
Adenoma						
Low grade	5	8		3	4	
High grade	0	3		0	7	
Traditional serrated	1	1		2	3	
NB			27/36 (75)			33/39 (85)
Hyperplastic/normal tissue	13	2		18	1	
Adenoma						
Low grade	6	10		3	5	
High grade	0	4		0	7	
Traditional serrated	1	0		2	3	
pCLE offline			26/37 (70)			31/40 (78)
Hyperplastic/normal tissue	16	7		21	6	
Adenoma						
Low grade	2	8		3	6	
High grade	0	1		0	4	
Traditional serrated	2	1		0	0	
pCLE online			26/37 (70)			32/40 (80)
Hyperplastic/normal tissue	15	6		21	5	
Adenoma						
Low grade	1	8		2	4	
High grade	2	2		0	7	
Traditional serrated	2	1		1	0	

No Cap, colonoscopy performed without an endoscopic distal attachment cap; Cap Used, colonoscopy performed with an endoscopic distal attachment cap.
Some information was unavailable regarding WL imaging diagnosis (n = 1, No Cap; n = 1, Cap Used) and NB imaging diagnosis (n = 2, No Cap; n = 1, Cap Used) and, therefore, could not been included in the summaries. Accuracy refers to presumed diagnosis of adenoma versus hyperplastic/normal tissue.

discovered polyps in total, on the basis on many prior trials involving colon polyps. For the comparison of groups (Cap Used vs No Cap), we expected around 60 polyps. Because the focus of this study was to gain a preliminary assessment of the potential utility of the use of a cap to guide future research, the analysis consisted of descriptive summaries only. Our primary summary measure was the proportion with a high score for the purpose of imaging quality. A score of either 4 or 5 was designated as a high score.

Results

Patient characteristics, including age, sex, race, patient history of CRC or adenoma, family history of CRC, and indication for procedure, were distributed similarly across the 2 study groups (**Table 1**).

For all 81 polyps identified, image quality and stability were similar between the 2 study groups. In specific, the proportion of images with a high quality score (4 or 5) was 74% (28/38) in the Cap Used group versus 79% (30/38) in the No Cap arm. We also observed that the use of the cap yielded a slightly lower proportion of images with high image stability score (45%; 18/40) in comparison with images collected without the cap (58%; 23/40) (**Table 2**). Higher confidence levels were also observed in the Cap Used group, with 84% (32/38) versus 68% (27/40) in the No Cap group (**Table 2**).

Both insertion and withdrawal times were faster with a cap than without a cap (data not shown). The number of polyps found was similar (n = 40, Cap Used group; n = 41, No Cap group) (**Table 2** and **Table 3**). Among polyp characteristics, the proportion of lesions that were neoplastic (including adenoma or traditional serrated adenoma) in the No Cap and Cap Used groups was 46% and 40%, respectively (**Table 2**).

When comparing diagnostic accuracy (adenoma vs non-adenoma) among different imaging methods (WL, NB, and pCLE offline and online), we found that the Cap Used group had slightly higher diagnostic accuracy estimates than were observed for the No Cap group for all imaging modalities (**Table 4**).

In both groups, overall image quality was better for lesions measuring 10 mm or greater, in comparison with lesions measuring between 1 and 9 mm (70% and 60% of acceptable images, respectively). The imaging quality and image stability were similar with and without a cap (**Table 5** and **Table 6**).

When assessing correspondence between the confocal Miami criteria and the histopathologic diagnosis, we found a stronger association with thickness, darkness, and vessels in the Cap Used group, but no association with the presence/absence of goblet cells (**Table 7**).

Discussion

Overall, this preliminary study did not yield sufficient evidence to support that the use of a cap improves the quality or stability

	Overall polyps identified (N = 38)	No Cap (n = 22)	Cap Used (n = 16)
Image quality, no. (%)			
1 = worst	0 (0)	0 (0)	0 (0)
2	1 (3)	1 (5)	0 (0)
3 = acceptable	8 (23)	5 (25)	3 (20)
4	19 (54)	10 (50)	9 (60)
5 = equal to histopathologic findings	7 (20)	4 (20)	3 (20)
Mean (SD)	3.9 (0.7)	3.9 (0.8)	4.0 (0.7)
Image stability, no. (%)			
1 = worst	3 (8)	2 (9)	1 (6)
2	7 (18)	4 (18)	3 (19)
3 = acceptable	11 (29)	5 (23)	6 (38)
4	10 (26)	6 (27)	4 (25)
5 = equal to histopathologic findings	7 (18)	5 (23)	2 (13)
Mean (SD)	3.3 (1.2)	3.4 (1.3)	3.2 (1.1)
Percent acceptable image	60 (10, 40, 70, 95)	65 (10, 40, 80, 95)	55 (15, 40, 70, 95)
Confidence level, no. (%)			
Low	9 (24)	8 (36)	1 (6)
High	29 (76)	14 (64)	15 (94)
Diagnosis, no. (%)			
Hyperplastic/normal tissue	29 (76)	16 (73)	13 (81)
Adenoma			
Low grade	8 (21)	5 (23)	3 (19)
High grade	1 (3)	1 (5)	0 (0)
Traditional serrated	0 (0)	0 (0)	0 (0)

Table 5 Offline probe-based confocal laser endomicroscopy (pCLE) image interpretation of 38 polyps, measuring between 1 and 9 mm, resected from 40 patients undergoing colonoscopy (January 10 – November 5, 2012) with or without an endoscopic distal attachment cap.

SD, standard deviation.
The sample median (minimum, 25th percentile; maximum, 75th percentile) is given for percent acceptable image. Information for some polyps identified was unavailable regarding image quality (n = 2, No Cap; n = 1, Cap Used). Percentage sums that do not equal 100 % are due to rounding.

	Overall polyps identified (N = 27)	No Cap (n = 12)	Cap Used (n = 15)
Image quality, no. (%)			
1 = worst	0 (0)	0 (0)	0 (0)
2	1 (4)	0 (0)	1 (7)
3 = acceptable	8 (31)	2 (17)	6 (43)
4	8 (31)	4 (33)	4 (29)
5 = equal to histopathologic findings	9 (35)	6 (50)	3 (21)
Mean (SD)	4.0 (0.9)	4.3 (0.8)	3.6 (0.9)
Image stability, no. (%)			
1 = worst	3 (11)	0 (0)	3 (20)
2	4 (15)	3 (25)	1 (7)
3 = acceptable	6 (22)	1 (8)	5 (33)
4	8 (30)	3 (25)	5 (33)
5 = equal to histopathologic findings	6 (22)	5 (42)	1 (7)
Mean (SD)	3.4 (1.3)	3.8 (1.3)	3.0 (1.3)
Percent acceptable image	70 (10, 40, 80, 95)	75 (25, 45, 90, 95)	50 (10, 30, 70, 95)
Confidence level, no. (%)			
Low	9 (35)	4 (33)	5 (36)
High	17 (65)	8 (67)	9 (64)
Diagnosis, no. (%)			
Hyperplastic/normal tissue	10 (37)	4 (33)	6 (40)
Adenoma			
Low grade	11 (41)	6 (50)	5 (33)
High grade	4 (15)	0 (0)	4 (27)
Traditional serrated	2 (7)	2 (17)	0 (0)

Table 6 Offline probe-based confocal laser endomicroscopy (pCLE) image interpretation of 27 polyps, measuring 10 mm or greater, resected from 40 patients undergoing colonoscopy (January 10 – November 5, 2012) with or without an endoscopic distal attachment cap.

SD, standard deviation.
The sample median (minimum, 25th percentile; maximum, 75th percentile) is given for percent acceptable image. Information for some polyps identified was unavailable regarding image quality (n = 1, Cap Used) and confidence level (n = 1, Cap Used). Percentage sums that do not equal 100 % are due to rounding.

Table 7 Correspondence of Miami classification system[1] with histopathologic findings for 81 (77 evaluable for Miami classification) polyps resected from 40 patients undergoing colonoscopy (January 10 – November 5, 2012) with or without an endoscopic distal attachment cap.

	No Cap			Cap Used		
	Normal tissue (n = 20)	Adenoma (n = 17)	Correspondence, no. (%) (n = 37)	Normal tissue (n = 24)	Adenoma (n = 16)	Correspondence, no. (%) (n = 40)
Crypt class			n/a			n/a
Round	5	1		6	0	
Stellate	11	5		14	4	
Irregular or villiform	2	10		3	10	
Disorganized	1	0		0	1	
Goblet cells			12/37 (32)			10/40 (25)
Absent	3	8		4	10	
Present	17	9		20	6	
Epithelial thickness			27/37 (73)			33/40 (83)
Uniform/thin	17	7		22	5	
Irregular/thick	3	10		2	11	
Epithelial darkness			27/37 (73)			33/40 (83)
Not dark	17	7		22	5	
Dark	3	10		2	11	
Vessels			26/36 (72)			32/40 (80)
Thin	16	7		22	6	
Dilated/irregular	3	10		2	10	

n/a, nonapplicable.
Information for some polyps identified was unavailable regarding crypt class (n = 2, No Cap; n = 2, Cap Used) and vessels (n = 1, No Cap).
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of pCLE images. This does not mean that it is not effective, and this trial is still a pilot study that was not powered to assess for statistical difference. However, a much larger, well-powered study may identify that image quality is improved with use of a cap.

Although promising, in vivo polyp-discrimination methods have not been widely endorsed. Methods that require mucosal staining have proved to be cumbersome for screening examinations. In addition, zoom (magnifying) endoscopes can be fragile and expensive, and regional differences in magnification offered by available video processors have limited the reproducibility of NB imaging – discrimination methods outside of Japan and the United Kingdom [8]. Although results of 1 small western study seem to support that mesh capillary vessel presence can be accurately assessed without the need for an optical magnification processor [9], differences in the processors' diagnostic ability have also been described [10]. Citing the limitations of electronic magnification in visual discrimination, Rex et al [10] introduced the concept of applying confidence levels to endoscopic prediction in the hope of improving predictive accuracy. Predictions of polyp histopathologic findings were made with high confidence 81 % and 92 % of the time for diminutive hyperplastic and adenomatous polyps, respectively. From this group, high levels of predictive accuracy were shown for both hyperplastic (95 %) and adenomatous (91 %) lesions [10]. Despite showing that mucosal patterns are highly accurate in predicting neoplasia, the lower than ideal confidence in predicting hyperplastic lesions (81 %) means that a large number of lesions would still require polypectomy.

Our group has evaluated advanced endoscopic imaging methods and pCLE for polyp discrimination. In a large, single-blind trial, pCLE was found to be superior to current state-of-the-art, NB or Fuji Intelligent Chromo Endoscopy (FICE), imaging. However, in neither method were critical thresholds needed to avoid the need for histopathologic evaluation reached [11].Furthermore, pCLE is a cumbersome process that requires exogenous fluorescein dye and expensive confocal probes.

As with all endoscopic imaging methods, pCLE relies on the ability of the operator to acquire images of high quality and interpret them with reliability and accuracy [6, 11]. Although pCLE offers greater convenience and compatibility with all standard endoscopes, the free-hand nature of holding the pCLE in contact with tissue presents challenges to gaining stable, high quality images [12]. Few studies with options to improve image stability have been published to date. The eCLE systems overcome this by applying suction to the tip of the endoscopes, which is integrated with the CLE imaging window [13]. A hand-held instrument with the purpose of providing contact force and better confocal images has been developed that may overcome natural bowel movements and also the subjective motion from the hand of the operator [14].

Our group previously published a study comparing the accuracy of standard imaging and pCLE for colorectal polyps. We have generally observed that pCLE has a lower diagnostic accuracy for imaging small polyps and speculate that this is due to difficulties in maintaining good probe contact and image stability [15].

A limitation of the current study is that it was performed in a single center that has substantial experience in pCLE. This experience may reduce the differences between different techniques (Cap Used vs No Cap) because we have a significant amount of experience with the free-hand methods. The study was also limited by small sample size and could only provide preliminary comparisons.

In summary, our study findings do not support that the use of a cap improves image stability, although it may increase the accuracy of pCLE and other imaging methods for small polyps. There is still need for larger randomized trials with different image stabilization techniques or devices when using pCLE technology.

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