Mucosal protective agents may improve healing of patients with endoscopic submucosal dissection-induced ulcers. The present study systematically evaluated published clinical trials to determine whether combined therapeutic use of mucosal protective agents and proton pump inhibitors can improve the outcome of patients with endoscopic submucosal dissection-induced ulcers compared to treatment with proton pump inhibitors alone. PubMed, the Cochrane Library, and the Igaku-Chuo-Zasshi database were searched to identify eligible randomized trials for systematic review. We identified 11 randomized trials for inclusion in our study (1,160 patients). Pooled endoscopic submucosal dissection-induced ulcer healing rates were 45.8% and 34.4% for patients with or without mucosal protective agents, respectively. The odds ratio was 2.28 (95% confidence interval, 1.57–3.31) with no significant study heterogeneity. In conclusion, the systematic review and meta-analysis showed that the combined therapeutic use of proton pump inhibitors and mucosal protective agents improved healing rates of endoscopic submucosal dissection-induced ulcers compared to treatment with proton pump inhibitor monotherapy.

**Methods**

Before performing the meta-analysis, we developed a protocol that included search strategies, criteria for study selection, the method of extraction of related data, methods for assessing study quality, and statistical methodology.

**Search strategy.** The electronic databases PubMed, the Cochrane Library, and the Igaku-Chuo-Zasshi in Japan (from 1950 to June 2014) were used to systematically search the literature for a combination of the following words: (endoscopic submucosal dissection OR ESD) AND (mucosal protective agents, mucosal defensive agents, rebamipide, ecabet sodium, polaprezinc, sucralfate, alginate, plaunotol, sofalcone, teprenone, irsogladine, misoprostol, OR aluminum-magnesium). Articles published in any language were included. Although abstracts occasionally include less information and may possess less accuracy, we retrieved them to reduce publication bias; in essence, studies with negative results are less likely to reach full publication.

**Inclusion and exclusion criteria.** Articles were considered eligible if the studies met the following inclusion criteria: (1) study type: RCTs; (2) population: patients who had undergone ESD; (3) intervention: an active treatment with PPI plus mucosal protective agents; (4) comparison group: treatment with PPI monotherapy; (5) outcome: reported healing rates of ESD-induced ulcers. The major exclusion criteria were: (1) a non-RCT; (2) administration of rebamipide in the control group; (3) no ulcer healing rates reported; or (4) duplicate publications, case reports and reviews.

**Data extraction.** Standardized data abstraction sheets were prepared. Data were extracted for study quality, endoscopic therapy use, medication duration, patient follow-up time, and sex and age of enrolled subjects. Key outcome data were abstracted from all included studies. All articles were examined independently for eligibility by two reviewers (T.N. and H.S.). Disagreements were resolved by consulting a third reviewer (N.Y.).

**Outcome measures.** The primary outcome measured was healing rates of ESD-induced ulcers. The ulcer stage was classified using the classification of Sakata and Miwa: active (A1 and A2), healing (H1 and H2), and scarring (S1 and S2). S-stage was defined as the healing of an artificial ulcer. The secondary outcome measured was safety, which was analyzed by evaluating complication rates.
Assessment of methodological quality. The methodological quality of each study was assessed using the risk-of-bias tool outlined in the Cochrane Handbook for Systematic Reviews of Interventions (ver. 5.1.0). Two reviewers (T.N. and H.S.) reviewed all studies and assessed 6 key aspects influencing quality of an RCT, including sequence generation, allocation concealment, blinding of both participants and outcome assessors, management of eventual incomplete outcome data, completeness of outcome reporting, and other potential threats to validity.

Statistical analysis. Data were entered into StatsDirect statistical software. The odds ratios (ORs) were calculated for ulcer healing rates with PPI plus mucosal protective agents compared to that with PPI monotherapy. We used a random-effect model to calculate summary ORs and 95% confidence intervals (CIs). Heterogeneity between the studies was assessed using Cochrane’s Q and I-Squared test. Because of the low power of the Q test, a cut-off value <0.10 was used to reject homogeneity, indicating heterogeneity. An I-squared score ≥50% indicated more than moderate heterogeneity. The subgroup analyses were performed for each individual mucosal protective agent that allowed the groups to be classified into patients who had received four- and eight-week treatments. To evaluate the statistical stability of this meta-analysis, we performed a sensitivity analysis to evaluate the effect of low-quality studies (conference abstracts). Finally, we used funnel plot asymmetry to detect any publication bias in the meta-analysis, and Egger’s regression test to measure funnel plot asymmetry.

Results

Literature search. Our database search yielded 109 citations (Fig. 1). After adjusting for duplicates, 63 studies remained. Of these, 37 studies were removed from consideration after reviewing the abstracts, based on exclusion criteria (20 unrelated topics, 5 reviews, 4 case reports, and 8 animal studies). The remaining 26 studies were examined in detail. Studies were then excluded due to lack of randomization (n = 6), control groups (n = 7), or reported ulcer healing rates (n = 2 conference abstracts). Finally, 11 studies (8 full papers and 3 conference abstracts) were included in the systematic review and meta-analysis.

Characteristics and quality of eligible studies. The characteristics of the 11 studies are summarized in Table 1. The risk of bias in the RCTs is shown in Table 2. In general, the 8 full paper

Table 1. Characteristics of studies included in the meta-analysis

<table>
<thead>
<tr>
<th>Author Year</th>
<th>Country</th>
<th>Mucosal protective agents</th>
<th>Patients number</th>
<th>Intervention</th>
<th>Duration (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kato 2010</td>
<td>Japan</td>
<td>Rebamipide</td>
<td>31</td>
<td>RPZ 10 mg/day</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>31</td>
<td>RPZ + rebamipide 300 mg/day</td>
<td></td>
</tr>
<tr>
<td>Fujiwara 2011</td>
<td>Japan</td>
<td>Rebamipide</td>
<td>31</td>
<td>OPZ 20 mg/day</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30</td>
<td>OPZ + rebamipide 300 mg/day</td>
<td></td>
</tr>
<tr>
<td>Araki 2012</td>
<td>Japan</td>
<td>Rebamipide</td>
<td>42</td>
<td>OPZ 20 mg/day, LPZ 30 mg/day or RPZ 10 mg/day</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>45</td>
<td>PPI + rebamipide 300 mg/day</td>
<td></td>
</tr>
<tr>
<td>Kobayashi 2012</td>
<td>Japan</td>
<td>Rebamipide</td>
<td>85</td>
<td>OPZ 20 mg/day or LPZ 30 mg/day</td>
<td>28-42</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>85</td>
<td>PPI + rebamipide 300 mg/day</td>
<td></td>
</tr>
<tr>
<td>Shin 2012</td>
<td>Korea</td>
<td>Rebamipide</td>
<td>129</td>
<td>Pantoprazole 40 mg/day</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>126</td>
<td>Pantoprazole + rebamipide 300 mg/day</td>
<td></td>
</tr>
<tr>
<td>Takayama 2013</td>
<td>Japan</td>
<td>Rebamipide</td>
<td>44</td>
<td>LPZ 30 mg/day</td>
<td>28/56</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>45</td>
<td>LPZ 30 mg/day, 5 days; then rebamipide 300 mg/day</td>
<td></td>
</tr>
<tr>
<td>Asakuma 2009</td>
<td>Japan</td>
<td>Ecabett</td>
<td>27</td>
<td>RPZ 20 mg/day</td>
<td>28/56</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>28</td>
<td>RPZ + ecabett 3 g/day</td>
<td></td>
</tr>
<tr>
<td>Hyun 2010</td>
<td>Korea</td>
<td>Ecabett</td>
<td>38</td>
<td>LPZ 30 mg/day</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>38</td>
<td>LPZ 30 mg/day, 7 days; then ecabett 3 g/day</td>
<td></td>
</tr>
<tr>
<td>Inaba 2010</td>
<td>Japan</td>
<td>Polaprezinc</td>
<td>80</td>
<td>LPZ 30 mg/day</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>79</td>
<td>LPZ + polaprezinc 150 mg/day</td>
<td></td>
</tr>
<tr>
<td>Yoshida 2013</td>
<td>Japan</td>
<td>Polaprezinc</td>
<td>27</td>
<td>OPZ 20 mg/day</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>23</td>
<td>OPZ + polaprezinc 150 mg/day</td>
<td></td>
</tr>
<tr>
<td>Miyahara 2013</td>
<td>Japan</td>
<td>Irsogladine</td>
<td>45</td>
<td>PPI</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>51</td>
<td>PPI + irsogladine</td>
<td></td>
</tr>
</tbody>
</table>

RPZ: rabeprazole, OPZ: omeprazole, LPZ: lansoprazole.
studies in the analysis had low risk of bias. The 3 conference abstracts had an unclear risk of bias. Six RCTs (3 full papers and 3 abstracts) did not describe the specific methods of random sequence generation and allocation concealment. Methods of blindness assessment were not described for 7 studies (4 full papers and 3 abstracts). The 3 abstracts did not adequately assess incomplete outcomes or how selective outcome reporting was avoided. All 8 full paper studies were free of other biases.

**Efficacy analysis.** Pooled healing rates were achieved for 266 of 581 patients (45.8%) treated with mucosal protective agents and for 199 of 579 patients (34.4%) who had not received mucosal protective agents (OR 2.28, 95% CI 1.57–3.31, \( p < 0.0001 \), Fig. 2). There was no significant heterogeneity among the trial results (\( \chi^2 = 13.0, \ p = 0.225, \ I^2 = 23% \)). In the subgroup analysis based on duration of treatment, we found that treatment with PPIs plus mucosal protective agents was more effective in healing ESD-induced ulcers than PPI monotherapy over both four- (OR 2.19, 95% CI 1.43–3.34, \( p = 0.0003 \), Fig. 3) and eight-week treatments (OR 3.03, 95% CI 1.42–6.48, \( p = 0.0043 \), Fig. 4).

Additive effects of individual mucosal protective agents were also analyzed (Table 3). Rebamipide and irsogladine were significantly effective, but the study on irsogladine was one of the conference abstracts. Ecabet sodium and polaprezinc were not significantly effective.

**Adverse events.** Three trials reported adverse events. The study by Fujiwara et al.\(^\text{(11)}\) reported that one patient in the PPI group experienced bleeding due to a post-ESD artificial ulcer. There were no other serious adverse events.

**Sensitivity analysis and publication bias.** To analyze statistical sensitivity of our meta-analysis, we excluded three low-quality studies (conference abstracts). Exclusion of these studies did not significantly alter the outcome of the meta-analysis. (OR 2.40, 95% CI 1.58–3.65, \( p = 0.0001 \), Fig. 5). The funnel plot had almost symmetrical distribution (Fig. 6), and Egger’s regression
test suggested no significant asymmetry of the funnel plot ($p = 0.15$), indicating no evidence of substantial publication bias.

**Discussion**

This systematic review and meta-analysis indicated that therapeutic use of PPIs plus mucosal protective agents is superior to PPI monotherapy for ESD-induced ulcers. We therefore expect that mucosal protective agents will become more widely utilized
Mucosal protective agents are safe and widely used as anti-ulcer drugs in East Asia. Rebamipide \(\text{2-(4-chlorobenzoylamino)-3-[2(1H)-quinolinon-4-yl] propionic acid; Otsuka Pharmaceutical Co., Ltd., Tokyo, Japan}\) exerts a preventive effect on gastric ulcer formation by inhibiting neutrophil activation.\(^{21,22}\) Rebamipide is an oxygen-radical scavenger, stimulates the generation of cytoprotective prostaglandins, and increases blood flow in the gastric mucosa.\(^{23–25}\) Ecabet sodium \(\text{(12-sulfodehydroabietic acid mono-sodium salt; Mitsubishi Tanabe Pharma Corporation, Osaka, Japan)\} has protective effects such as endogenous prostaglandins and nitric oxide synthesis and increases blood flow in the gastric mucosa.}\(^{26}\) Ecabet sodium also exhibits a bactericidal effect against \text{Helicobacter pylori} by inhibiting bacterial urease activity.\(^{27}\) Polaprezinc \(\text{[N-(3-amino propionyl)-L-histidine zinc; Zeria Pharmaceutical Co., Ltd., Tokyo, Japan\} promotes ulcer healing with actions such as prostaglandin-independent cytoprotection, antioxidant activity, leukocyte inactivation, and membrane stabilization.}\(^{28}\) Moreover, polaprezinc stimulates the production of insulin-like growth factor 1, thus promoting mucosal wound healing.\(^{29}\) Irsogladine \(\text{[2,4-diamino-6-(2,5-dichlorophenyl)s-triazine; Nippon Shinyaku Co., Ltd., Kyoto, Japan\] suppresses free radical production, facilitates intercellular communication via gap junctions, and enhances gastric mucosal blood flow.}\(^{30}\) These actions accelerate mucosal or submucosal reconstruction and enhance the quality of ulcer healing.

In clinical practice, it is important to understand which mucosal protective agents are most effective for improving healing of gastric ulcers. Among the drugs analyzed in our study, rebamipide and irsogladine were significantly effective. However, the study on irsogladine was of low quality. Further, it was difficult to evaluate whether Ecabet sodium and polaprezinc were effective because the sample sizes in these studies were not large enough to uncover significant differences. Although rebamipide seems most effective, well-designed trials are needed to confirm these findings.

The costs of rebamipide, ecabet sodium, polaprezinc, and irsogladine for 28 days are ¥1,462, ¥1,271, ¥2,106, and ¥1,840, respectively. The costs of rabeprazole (20 mg/day) and lansoprazole (30 mg/day) for 28 days are ¥7,448 and ¥4,648, respectively. The costs of mucosal protective agents are relatively low. Takayama \textit{et al.}\(^{15}\) reported that rebamipide monotherapy was equivalent to treatment with a PPI in the healing of ESD-induced ulcers and treatment with rebamipide was more cost-effective than treatment with the PPI. Mucosal protective agents might be able to reduce the costs by reducing the dose of PPI.

The present systematic review and meta-analysis has several limitations that need to be taken into account when interpreting the results. None of the included RCT trials met all quality criteria, which may have influenced the results. In addition, most participants in the studies were Japanese and Korean; therefore, these results may not be generalizable to other races.

In conclusion, our analysis demonstrates that supplementing PPI therapy with mucosal protective agents could improve healing of ESD-induced ulcers.
Acknowledgments

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Conflict of Interest


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