excellent bioadhesion property [28–30]. Lectins, Polyox WSR, and thiolated polymers are new generation polymers [14].

Patil and colleagues developed a mucoadhesive tablet of lafutidine. They studied various natural polymers, namely karaya gum, xanthan gum, and sodium alginate. The natural polymers were used to prepare different batches of tablets. It was observed that tablets containing 90 mg of xanthan gum demonstrated better results for the percentage of cumulative drug release at 12 h (99.50 ± 0.35%), lag time in buoyancy (11 ± 2 s), and mucoadhesion time (12 h). The optimized formulation demonstrated a mucoadhesive strength of more than 35 g. In vivo study performed in rabbits by X-ray imaging demonstrated that the tablet was well adhered to the rabbit's stomach for more than 10 h. The lafutidine tablets were found to be completely stable after storage at 40°C and 75 ± 5% relative humidity for 3 months. The formulation was found to improve bioavailability and reduce dosing frequency of lafutidine [31].

Pandey et al. developed and evaluated a GRDDS of lercanidipine HCl in the form of a bilayer mucoadhesive patch. The patch comprised Eudragit RLPO and RSPO as the rate-controlling film and various hydrophilic polymers that formed the mucoadhesive film. It was found that the optimized patches were successful in controlling the drug release for 12 h. The mucoadhesion strength was found to be between the range of 4.05 ± 0.4 N and 4.52 ± 0.12 N. In vivo bioavailability studies in rabbits indicated that the patches could be retained for a longer time in the stomach and offer a promising strategy for the delivery of lercanidipine HCl [32]. Marketed preparations of mucoadhesive drug delivery systems include Suradrin® tablet (nitroglycerin), Attach® tablet (triamcinolone acetonide), and Sucralfate® (aluminium hydroxide) [33].

The efficiency of these systems may be reduced due to constant turnover of mucus. The other disadvantage is that because these systems possess the ability to link to the epithelial mucosa, they may link to other mucosa such as that of the esophagus [9]. These may affect the drug absorption pattern and stability.

Thus, GRDDS are advantageous for narrow absorption window drugs or drugs having a local effect on specific site of the GIT. The development of these novel systems requires in-depth knowledge of anatomy and physiology of the GIT. The formulation of systems that will stay in the stomach during fasted state still remains a challenge. In this regard, floating systems offer the best perspectives [9]. Also, combination of various approaches will help to improve the efficiency of GRDDS. Abduljabbar and coworkers developed a GRDDS tablet of ranitidine HCl combining the floating approach and bioadhesive approach. Ranitidine HCl has low oral bioavailability due to absorption from the intestine and metabolism in the colon. A 3(2) factorial design was used to assess the effects of HPMC K100M: drug ratio and Carbopol 971 on the tablet's characteristics. After the statistical analysis, a significant effect was observed on the maximum detachment force, swelling index, and drug release after 6 h because of the use of a combined approach. The optimized formulation demonstrated a good floating behavior of up to 6 h with appropriate bioadhesion. In the future, GRDDS can be expected to become even more important in drug delivery systems, ultimately leading to efficacious drug delivery [34].

3. COLON-TARGETED DRUG DELIVERY SYSTEMS

The colon is the largest part of the large intestine, which removes water and unabsorbed part from the digested food. Targeting of the drug at the colon is advantageous in the treatment of various colonic diseases, including inflammatory bowel disease and colon cancer. Also, the colon is the best absorption site for peptides and proteins because of less enzymatic activity, less proteolytic activity of colonic mucosa when compared with the small intestine, and longer residence time of up to 5 days [35, 36]. The other advantages with colon-targeted drug delivery include the improved bioavailability of peptide and protein drugs, reduction in the dose size as the drug is saved from first-pass metabolism, reduction in the dosing frequency resulting in a daily lower cost for the patients, flexibility in designing of colonic drug delivery systems, improved patient compliance, delivery of drugs close to the target resulting in reduced adverse effects, and protection of the colonic mucosa from irritating drugs [37]. Ulcerative colitis is treated with glucocorticoids that upon administration produces systemic side effects such as immunosuppression, adenosuppression, and bone resorption. Therefore, targeted delivery to the colon will not only reduce the dose, but also lessen the associated side effects [35]. Thus, colon-targeted systems play a significant role in the effective delivery of drugs.

The drugs that can be formulated as colon-targeted delivery systems include drugs that are used for local effects in the colon, such as nifedipine and amyline; drugs that have poor absorption in the upper GIT, such as ibuprofen, cyclosporine, and theophylline; drugs that are used for the treatment of colon cancer, such as glucagon and pseudoephedrine; drugs that degrade in the