with the mucus. So, it is also important to consider the mucus turnover of the site of administration for an efficient mucoadhesive drug delivery system. The factors which can alter mucus turn over include the presence of food or irritant and disease status. Theoretically the presence of adhesive should also alter the turnover but no published data is available on this [134].

#### 6.2.4. Disease state

Pathological conditions such as gastric ulcer, cold, cystic fibrosis, asthma, inflammation, candidiasis, respiratory infections, and allergic responses alter not only the turnover of the mucus but also the composition and viscosity of the mucus. This seriously affects the mucoadhesion. That is why it is important to consider these changes to develop a mucoadhesive dosage form for a specific disease and such dosage form should be tested under similar condition or representative testing models.

#### 6.2.5. Type of mucin

Besides, other physiological factors, the types of mucin that constitute the mucosal layer also play an important role in determining the nature of interaction between polymer and mucus. Cysteine-rich mucin such as MUC2 and MUC5, as illustrated in Table 1, can undergo disulfide exchange reaction with thiomers which show a significantly higher degree of adhesion as compared to hydrogen bonding or electrostatic interaction.

## 7. MUCOADHESIVE DRUG DELIVERY SYSTEMS

The concept of mucoadhesion is so useful and versatile that as it has opened up new channel to develop various drug delivery systems. The advantages of mucoadhesive drug delivery systems are summarized in Fig. 7. Some of the drug delivery systems that has utilized the idea of mucoadhesion in recent years are.

### 7.1. In Situ Gelling Formulations

In situ gelation involves the formation of gel from sol, either at the site of administration or at the site of action triggered by stimuli such as light, temperature, pH, or the presence of ions. When this drug delivery system is rendered mucoadhesive, it enhances the efficiency of drug delivery system by increasing the residence time [135, 136]. Commonly in situ gel formulations contain poloxomer alone or in combination with chitosan or hyaluronic acid [137, 138]. Gratieri et al. conducted a human in vivo study of ploxamer/chitosan in situ gelling formulation for ocular delivery and found fourfold increase in retention time as compared to conventional drug solution [137]. Ranch et al. developed an ocular in situ gel from by combining gellan gum and carbopol 934P. The formulation showed 2.5 folds increased occular retention time in comparison to marketed gel when instilled to human eye in an in vivo study [139].

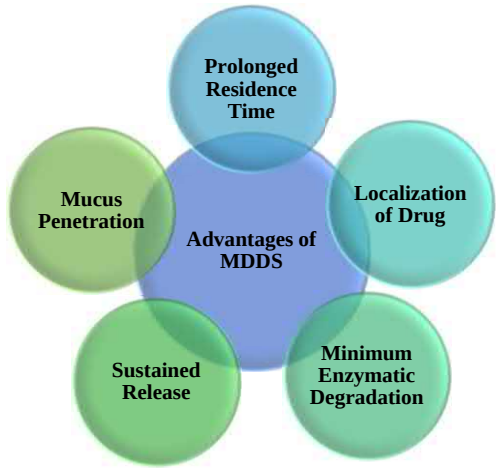


FIG. 7 Advantages of mucoadhesive drug delivery systems.

### 7.2. Electrospun Nanofibers

Electrospinning is a technique to produce very fine fiber ranging in micrometer to nanometer in diameter. In this technique, solution or fused form of polymer is released from a syringe and is spun on a drum under the influence of strong electric field. This technique combines with mucoadhesive properties resulted in preparation of mucoadhesive electropunk nanofibers [140]. Polyvinyl alcohol, chitosan and its blend polyvinyl alcohol, polylacto glycolic acid, PVP, polyethylene oxide and their combination are reported for the preparation of mucoadhesive elector-spun nanofibers [141–144].

### 7.3. Mucoadhesive Nanoparticles

Nanoparticles have diameter in nanometer range and possess certain properties and functions that differ significantly from original material when it interacts at cellular level. Due to higher penetration in mucus gel layer, nanoparticles show more mucoadhesion as compared to micro particles [145]. Polymers like polyacrylates, PLGA, chitosan are being studied to prepare these mucoadhesive nanoparticles [146]. Solid lipid nanoparticles (SLNs) have also gained attention of researchers in