



Patient-Centric Drug Delivery Systems: Recent Advances in Orodispersible, Buccal, Effervescent and Multiparticulate Formulations - A Contemporary Narrative Review

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Abstract

Patient-centric drug delivery has evolved from a predominantly product-centred approach toward formulation design that explicitly considers the needs, capabilities, preferences and real-world use conditions of patients and caregivers. Conventional oral dosage forms remain the preferred route for many therapies, yet tablet size, swallowing difficulty, unpleasant taste, dosing complexity, delayed onset, poor dose flexibility and the need for water can compromise acceptability and adherence. Orodispersible tablets and films, buccal systems, effervescent formulations and multiparticulate dosage forms provide complementary solutions to these limitations. This review critically discusses the formulation principles, excipient selection, manufacturing technologies, performance attributes and patient-relevant considerations associated with these four platforms.

Particular attention is given to superdisintegrants and taste-masking approaches in orodispersible systems; mucoadhesive polymers, permeation enhancers and physicochemical drug properties in buccal delivery; acid-base chemistry, moisture control and manufacturing considerations in effervescent systems; and pellets, granules, microspheres and mini-tablets as flexible multiparticulate platforms.

Keywords: patient-centric drug delivery; orodispersible tablets; orodispersible films; buccal delivery; effervescent dosage forms; multiparticulate systems; mini-tablets; pellets; patient acceptability; pharmaceutical formulation

Introduction

The success of a pharmaceutical product depends not only on pharmacological efficacy but also on whether the intended patient can and will use the dosage form correctly. Patient-focused drug development has increasingly emphasized systematic incorporation of patient and caregiver perspectives into medical product development, including attributes that affect convenience, administration and acceptability [1,2]. In pharmaceutical technology, this principle translates into designing dosage forms around the interaction between the active pharmaceutical ingredient (API), excipients, manufacturing

process, packaging and the practical capabilities of the end user. Patient-centricity therefore extends beyond the traditional objectives of stability, potency and dissolution and includes the ability to swallow, taste, handle, open, measure, administer and continue treatment as intended [3].

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The need for patient-centric oral formulations is particularly evident in children, older adults and individuals with dysphagia, neurological disorders, cognitive impairment or other barriers to conventional tablet and capsule use. Regulatory guidance for paediatric medicines specifically identifies palatability, swallowability, dosage, dosing frequency, handling complexity, administration devices and container-closure systems as formulation factors that can influence patient acceptability [3]. Similar considerations apply to older adults, for whom tablet size, shape, mouthfeel, dosing burden and manual handling can affect the usability of a medicine [4]. Thus, formulation development should ideally identify the target population early and translate patient needs into measurable critical quality attributes (CQAs).

Among oral dosage technologies, four platforms are particularly relevant to patient-centred formulation: orodispersible systems, buccal dosage forms, effervescent formulations and multiparticulate systems. Orodispersible tablets (ODTs) and films are designed to disintegrate or dissolve rapidly in the oral cavity, often without water, thereby addressing swallowing and administration barriers [5–8]. Buccal systems place the formulation in intimate contact with the buccal mucosa and may provide local or systemic delivery while potentially avoiding gastrointestinal degradation and part of the hepatic first-pass effect [9–12]. Effervescent systems use an acid–base reaction to generate carbon dioxide when exposed to water, rapidly producing a palatable solution or dispersion and potentially improving dissolution and ease of administration [13,14]. Multiparticulates divide the dose among multiple small units such as pellets, granules or mini-tablets, providing opportunities for flexible dosing, modified release, taste masking and reduced dose-dumping risk [15–18].

Although these platforms are often discussed separately, they share a common development philosophy: the formulation should be engineered to reduce the practical burden of medication use while maintaining robust pharmaceutical quality. The present review therefore integrates these technologies from a patient-centric perspective and emphasizes formulation chemistry, excipient functionality, manufacturing, evaluation and

translational considerations rather than presenting them as isolated dosage-form categories.

Concept of Patient-Centric Pharmaceutical Formulation

Patient-centric formulation can be defined as the deliberate design of a medicine to meet relevant patient and caregiver needs while maintaining the required quality, safety and efficacy. The concept is broader than 'patient-friendly' formulation because it requires structured identification of patient needs and their translation into product and process specifications. FDA's patient-focused drug development framework encourages systematic collection and use of patient experience data in product development and regulatory decision-making [1,2,19]. From a formulation perspective, attributes such as dosage form size, route, dose volume, taste, texture, administration time, dosing frequency, need for water, packaging and handling can all influence product acceptability.

Patient-centric development is closely aligned with Quality by Design. The Quality Target Product Profile (QTPP) should include patient-relevant requirements in addition to conventional pharmaceutical targets. For example, an ODT intended for an older adult may require rapid disintegration, low friability, manageable tablet dimensions and a pleasant mouthfeel. A paediatric multiparticulate may require flexible dosing, acceptable taste, safe excipients and compatibility with an administration vehicle. A buccal film may require adequate adhesion without excessive residence discomfort, sufficient mechanical strength and a controlled release profile. A patient-centric QTPP therefore connects the therapeutic goal with the human factors that determine whether the product can be used successfully [20,21].

An important emerging principle is the distinction between a measured quality attribute and a patient-relevant quality attribute. Conventional specifications can ensure dose uniformity, assay, dissolution and stability, but these parameters may not fully capture acceptability. Recent work on patient-centric quality standards argues that critical attributes should be evaluated according to their relevance to patient exposure, safety and efficacy [19]. This perspective encourages formulation scientists to incorporate human-

centred attributes such as palatability, swallowability, texture, handling and administration burden into development and control strategies.

Patient Needs and Target Populations

The target population should be defined before selecting a dosage form. Children often require low and flexible doses, palatable preparations and formulations that can be administered with minimal caregiver manipulation. Older adults may experience dysphagia, reduced saliva production, impaired vision or reduced manual dexterity. Patients with neurological disorders may have difficulty coordinating swallowing or may require rapid administration during symptomatic episodes. Individuals taking multiple medicines may benefit from reduced dosing frequency, simplified administration or dosage forms that combine immediate and modified release. These needs explain why no single patient-centric dosage form can be universally preferred.[5,13]

Acceptability is multidimensional. Palatability includes taste, smell, aftertaste and mouthfeel, whereas usability includes the physical and cognitive actions required before and during administration. A formulation can therefore fail despite excellent pharmacotechnical performance if it is excessively bitter, fragile, difficult to open, difficult to dose accurately or unpleasant to swallow. Reviews of patient acceptability emphasize that dosage form choice should consider age, disease state, dose, administration setting and user characteristics [20]. For paediatric medicines, EMA specifically recommends integrating patient acceptability into pharmaceutical development rather than treating it as a late-stage consideration [3].

Orodispersible Drug Delivery Systems

Orodispersible Tablets

Orodispersible tablets are uncoated solid dosage forms intended to be placed in the mouth, where they disperse rapidly before swallowing. The European Pharmacopoeia specifies disintegration within 3 minutes under the relevant test conditions, while FDA guidance provides a regulatory framework for designating products as orally disintegrating tablets [5,21]. In practice, successful ODT development seeks much faster

in-mouth dispersion, adequate mechanical integrity during handling, acceptable mouthfeel and protection against environmental moisture.

The central formulation challenge is to create a tablet that is mechanically robust during manufacture and handling yet rapidly wetted and disintegrated in the oral cavity. Superdisintegrants such as crospovidone, croscarmellose sodium and sodium starch glycolate are commonly used to promote rapid breakup through swelling, wicking or a combination of mechanisms. Mannitol and related polyols are frequently selected as diluents because of their water solubility, pleasant cooling sensation and relatively favourable mouthfeel. However, the optimal excipient combination depends on drug dose, particle size, compressibility, hygroscopicity, taste and desired mechanical strength [6–8].

Manufacturing method strongly influences ODT performance. Direct compression is attractive because it is simple and scalable, but it requires excipients with good flow and compactability. Wet granulation can improve content uniformity and flow but introduces moisture and drying steps that may be undesirable for moisture-sensitive drugs. Moulding can produce porous tablets with rapid disintegration, whereas freeze-drying can generate highly porous oral lyophilisates with very fast dispersion but often at the cost of mechanical fragility. Sublimation and spray-drying approaches can also increase porosity. More recently, additive manufacturing has enabled highly customized oral dosage forms and complex release architectures [7,15].

Taste masking is often the decisive patient-centric challenge. Bitter APIs can be incorporated into ion-exchange resin complexes, polymeric coatings, cyclodextrin complexes, lipidic carriers or microencapsulated particles before compression. Sweeteners and flavours may improve sensory perception but cannot always compensate for a highly bitter API. The balance between taste masking and rapid drug release is particularly important because an ODT rapidly exposes the drug to saliva. Therefore, dissolution testing alone is insufficient; formulation development should also consider drug release in saliva, taste exposure time and mouthfeel.

Orodispersible Films

Orodispersible films (ODFs) are thin polymeric matrices that rapidly wet, hydrate and disintegrate or dissolve in the oral cavity. Their thin geometry, low weight and flexibility can make them attractive for patients who dislike tablets or have difficulty swallowing conventional solid dosage forms [7,8,22]. Films can also provide dose flexibility through defined strip dimensions, although cutting should only be considered when the product is designed and validated for such use. Film formulation commonly includes a film-forming polymer, plasticizer, API, sweetener or flavour, saliva-modifying agent and, when necessary, a taste-masking system. Hydroxypropyl methylcellulose, pullulan, hydroxypropyl cellulose, polyvinyl alcohol and related polymers have been explored because they provide film formation with varying mechanical and hydration properties. Plasticizers such as glycerol or polyethylene glycol can increase flexibility but may also influence moisture uptake, tensile strength and disintegration. Recent reviews highlight solvent casting as a widely used method while also describing hot-melt extrusion, electrospinning and 3D printing as emerging manufacturing approaches [7,22,23].

The critical quality attributes of ODFs extend beyond thickness and drug content. Tensile strength, percentage elongation, folding endurance, surface pH, disintegration time, dissolution, moisture content and content uniformity are commonly evaluated. However, a genuinely patient-centric ODF should additionally be evaluated for taste, mouthfeel, strip size, ease of removal from packaging and resistance to accidental handling damage. The interaction of film-forming polymers with saliva and oral movement is especially important because a film can meet laboratory mechanical criteria yet feel sticky or unpleasant in the mouth.

Recent Direction in Orodispersible Systems

Recent development is moving from simple rapid disintegration toward multifunctional and personalized oral dosage forms. Nanoparticle-loaded films, multilayer films, 3D-printed ODTs and films, and formulations containing poorly soluble drugs illustrate how the platform can be adapted to different biopharmaceutical challenges [7,15,24]. Instrumental methods capable of

relating disintegration behaviour to texture and palatability are also emerging, supporting a more objective approach to patient-centred development [25]. Nevertheless, advanced manufacturing should be adopted only when it solves a meaningful formulation or patient problem rather than being used as technology for its own sake.

Buccal Drug Delivery Systems

The buccal route offers a distinct patient-centric option because the formulation is placed between the cheek and gum, where the relatively accessible mucosa can support local or systemic drug delivery. Buccal administration may reduce exposure of the API to the acidic gastrointestinal environment and, depending on the drug and site of absorption, can reduce intestinal and hepatic first-pass metabolism [9–12]. The route is therefore particularly interesting for drugs that have poor oral bioavailability because of first-pass metabolism, gastrointestinal instability or absorption limitations.

Buccal dosage forms include tablets, patches, films, wafers, gels and more advanced polymeric or nanoparticulate systems. The formulation must achieve an appropriate balance between adhesion, hydration, drug release and patient comfort. Excessively strong adhesion can make removal uncomfortable, whereas insufficient adhesion may result in premature detachment due to saliva and tongue movement. The mucosal environment is continuously washed by saliva, and the formulation is subjected to mechanical stress; therefore, residence time is a critical quality attribute [6,8,14,26].

Mucoadhesive polymers are central to buccal formulation. Chitosan, carbomers, cellulose derivatives, polyacrylic acid derivatives and natural polysaccharides have been widely investigated. Mucoadhesion can involve hydrogen bonding, electrostatic interactions, polymer interpenetration and secondary chemical interactions between the polymer and mucin. Polymer molecular weight, degree of substitution, hydration rate, crosslink density and charge can influence adhesion. Recent reviews emphasize that polymer chemistry and the physiological characteristics of the mucosa must be considered together when designing buccal systems [9,10].

Drug permeability is another major determinant of performance. Hydrophilic drugs may have inadequate transcellular permeability, while highly lipophilic compounds may partition strongly into the mucosa or have poor aqueous dissolution. Permeation enhancers, pH modifiers, ion-pairing strategies, enzyme inhibitors and prodrug approaches have therefore been investigated. A review focusing on BCS Class III drugs highlighted the potential roles of permeation enhancers, mucoadhesive polymers, pH modifiers, ion pairing and prodrugs in improving buccal absorption [12]. These strategies should be selected carefully because enhancement of permeability can also increase local irritation or compromise mucosal integrity.

Buccal films have gained particular interest because they can combine low dose volume, flexibility and rapid or sustained release. Cellulose ethers and other film-forming polymers can be tailored to provide either rapid dissolution or prolonged mucoadhesion [10,23]. Emerging manufacturing approaches include electrospinning, electrospraying, 3D printing and hot-melt extrusion. Nanotechnology can further modify solubility, permeability and release characteristics. However, clinical translation requires robust assessment of residence time, mucosal tolerance, variability in saliva, patient comfort and real-world administration.

Effervescent Drug Delivery Systems

Effervescent dosage forms provide a patient-centric alternative when swallowing conventional solid forms is difficult or when rapid dispersion and improved palatability are desirable. Their fundamental mechanism is an acid-base reaction between an organic acid and a carbonate or bicarbonate source in the presence of water, producing carbon dioxide. The resulting effervescence promotes rapid disintegration or dissolution and can produce a drinkable preparation. Common acid components include citric and tartaric acid, while sodium bicarbonate is frequently used as the alkaline component [13,14].

The chemistry of effervescence is simple but formulation control is demanding. Acid-base stoichiometry affects carbon dioxide generation, residual pH and the sensory characteristics of the

final solution. Excess acid may produce an overly acidic preparation, whereas excess bicarbonate can result in alkaline taste and residual material. Water activity is particularly important because premature contact with atmospheric moisture can initiate the reaction, causing loss of effervescence, caking and reduced stability. Consequently, moisture-resistant excipients, controlled manufacturing humidity and protective packaging are essential.

Effervescent formulations can be produced by dry granulation, wet granulation under controlled conditions, melt granulation and other specialized approaches. The choice depends on the moisture sensitivity of the formulation and the desired granule properties. Granule size distribution, flow, compressibility, effervescence time, carbon dioxide generation, solution pH, assay, dissolution and stability should be considered during development. Recent literature has expanded effervescent technology beyond conventional rapid-release products toward controlled-release, floating and more advanced drug-delivery applications [13].

The patient-centric advantages include administration as a drink, rapid dissolution, potentially improved taste and reduced swallowing burden. However, effervescent products can be unsuitable for some patients because of sodium or electrolyte load, volume of water required, acid sensitivity, or the need to wait for complete dissolution. The dosage form should therefore be selected based on patient and therapeutic requirements rather than assuming that a liquid produced by effervescence is universally preferable.

Multiparticulate Drug Delivery Systems

Multiparticulate systems divide the total dose into numerous discrete subunits, including granules, pellets, microspheres, microparticles and mini-tablets. These subunits can be administered as capsules, sachets, dispersible formulations or compressed into larger tablets. The multiple-unit concept offers several advantages over monolithic dosage forms, including more uniform distribution through the gastrointestinal tract, flexible release modulation and potentially reduced consequences of localized failure or dose dumping [15–18].

Pellets are among the most established multiparticulate units. Extrusion–spheronization, solution or suspension layering, powder layering and related techniques can produce relatively spherical units that are subsequently coated with functional polymers. By changing coating composition and thickness, drug release can be modified to provide immediate, delayed, sustained or pulsatile profiles. Mini-tablets offer another route to multiparticulate design and can combine the dosing and manufacturing advantages of tablets with the physiological advantages of multiple-unit systems [17,18].

Patient-centricity is particularly relevant to multiparticulates because the small units can improve swallowability and allow flexible dosing. Paediatric formulations may use mini-tablets, granules or pellets that can be administered with an age-appropriate vehicle, while modified-release products can reduce dosing frequency. However, the administration medium can influence drug release, dose recovery and stability. Food effects and the risk of inappropriate manipulation should therefore be considered. The formulation should include clear administration instructions and, where appropriate, device-assisted dosing.

A key formulation challenge is maintaining the functional performance of coated subunits during subsequent processing. When coated pellets are compressed into tablets, compression forces may damage the coating and cause premature drug release. This issue has been extensively discussed for multiple-unit pellet systems and remains important when developing patient-centric multiparticulate tablets [16]. Protective coating design, cushioning excipients and optimized compression conditions can help preserve release characteristics.

Recent work has broadened multiparticulate systems to include microparticles, nanoparticles and multifunctional multi-unit platforms [15]. Such systems can provide simultaneous immediate and modified release, combination therapy or site-specific release. In parallel, additive manufacturing and process analytical technologies may support more precise control of subunit architecture and release. The major opportunity is to integrate multiparticulate technology with dose flexibility and personalized

therapy without compromising manufacturability or stability.

Formulation Components and Their Patient-Centric Role

Excipients are not merely processing aids; they directly influence patient experience. The selection of diluents, binders, disintegrants, film-formers, plasticizers, sweeteners, flavours, lubricants, coating polymers and permeation enhancers should therefore be linked to the intended patient population. For example, a mannitol-based ODT may provide a pleasant mouthfeel, while a high-viscosity polymer may improve buccal residence but produce an undesirable sticky sensation. Similarly, sodium bicarbonate may be effective in an effervescent formulation but may require attention to total sodium exposure.

Taste masking deserves special attention because taste is a major determinant of oral medicine acceptability. The strategy should be selected according to API dose, bitterness intensity, aqueous solubility and required release site. Polymer coating, ion-exchange resins, cyclodextrins, complexation and microencapsulation can reduce immediate exposure of the drug to taste receptors. However, excessive coating can delay dissolution or reduce dose availability. Thus, taste masking should be developed together with dissolution rather than as an independent optimization target.

Polymer functionality is also central to patient-centric delivery. Hydrophilic polymers can rapidly hydrate and promote disintegration, whereas crosslinked or hydrophobic polymers can retard release. Mucoadhesive polymers provide residence at the buccal surface, while coating polymers determine the release behaviour of pellets and mini-tablets. Understanding polymer–drug interactions, polymer hydration, viscosity, glass transition, swelling and erosion enables formulation scientists to rationally tailor dosage-form performance.

Manufacturing Technologies and Emerging Approaches

Manufacturing technology should be selected according to the target product profile rather than novelty alone. Direct compression remains

attractive for ODTs because it is scalable and economical, while lyophilization can provide extremely rapid oral dispersion. Solvent casting is widely used for films because it permits controlled film thickness and composition. Extrusion-spheronization is established for pellets, and coating processes allow controlled release. Effervescent systems require particularly stringent moisture control throughout processing and packaging [12,27].

Advanced manufacturing is increasingly influencing patient-centric formulation. Three-dimensional printing can create individualized doses, complex internal geometries, multilayer structures and combination products. Hot-melt extrusion can produce solid dispersions, films and modified-release matrices without solvents. Electrospinning can generate high-surface-area fibrous mats suitable for fast-dissolving or controlled-release oral and buccal systems. These approaches may ultimately support personalized dosing, but scale-up, process validation, raw-material variability, residual solvent or thermal degradation, equipment qualification and regulatory control remain significant considerations [7,15,22]. Quality by Design provides a systematic framework for managing these variables. Critical material attributes and critical process parameters should be linked to CQAs such as disintegration, tensile strength, adhesion, dissolution, content uniformity, effervescence time and stability. Design of Experiments can identify interactions between formulation variables, while process analytical technologies and multivariate analysis can support real-time process understanding. Importantly, patient-centric CQAs should be incorporated into the QTPP rather than added after formulation optimization.

Evaluation of Patient-Centric Dosage Forms

Conventional pharmacopoeial tests remain essential, but they should be complemented by

patient-relevant evaluation. ODTs require assessment of weight variation, hardness, friability, drug content, wetting time, disintegration and dissolution. ODFs additionally require thickness, folding endurance, tensile strength, percentage elongation, surface characteristics and moisture content. Buccal systems require mucoadhesive strength, residence time, swelling, drug release and permeability. Effervescent systems require effervescence time, solution pH, carbon dioxide generation, dissolution and moisture-related stability. Multiparticulates require particle-size distribution, flow, friability or mechanical strength, coating integrity, content uniformity and release performance[14,22]. Sensory and human-factor evaluation is increasingly important. Palatability may be assessed using validated taste panels, electronic tongues, sensory scales or appropriately designed acceptability studies. Texture and mouthfeel can be investigated using instrumental methods that quantify mechanical behaviour during oral processing. Recent work has explored instrumental prediction of disintegration and texture-related palatability for ODTs [28]. Such approaches are valuable because they can reduce reliance on subjective assessment during early development, although human acceptability remains the ultimate clinical objective. Administration testing should also mimic real-world use. For a paediatric multiparticulate, the product should be evaluated with the intended vehicle and dosing device. For an ODF, opening the pouch and placing the film in the mouth should be considered. For an effervescent product, the preparation time, required water volume and complete dissolution should be evaluated. For a buccal formulation, the effect of saliva and normal oral movement should be incorporated into performance testing. These studies bridge the gap between laboratory quality and actual usability.

Comparative Formulation Framework[7,12,16,24,26]

Platform	Primary patient need	Key formulation focus	Major advantages	Important limitations	Typical CQAs
Oro-dispersible tablet	Swallowing difficulty; no-water administration	Superdisintegration, porosity, taste masking	Rapid administration; compact; accurate unit dose	Fragility, moisture sensitivity, taste exposure	Disintegration, friability, dissolution, palatability

Oro-dispersible film	Swallowing difficulty; flexible administration	Film-former, plasticizer, taste masking	Thin, portable, rapid dispersion; potential dose personalization	Mechanical weakness, moisture, packaging	Disintegration, tensile strength, elongation, drug content
Buccal film/tablet/patch	Avoid GI exposure; local/systemic mucosal delivery	Mucoadhesion, permeability, release control	Potential first-pass reduction; local targeting	Mucosal irritation, saliva washout, residence variability	Mucoadhesion, residence time, permeation, release
Effervescent formulation	Easy liquid administration; rapid dispersion	Acid-base balance, moisture control, taste	Rapid dissolution; palatable liquid; reduced swallowing burden	Moisture sensitivity; sodium/acid load; preparation step	Effervescence time, pH, CO ₂ generation, dissolution
Multiparticulate	Dose flexibility; swallowing; modified release	Pellet/mini-tablet size, coating, release design	Reduced dose dumping risk; flexible release; dose titration	Manufacturing complexity; food/vehicle effects	Size distribution, coating integrity, content uniformity, dissolution

Table 1. Patient-centric comparison of major formulation platforms. The most appropriate platform should be selected according to the API properties, therapeutic objective, target population, administration environment and required release profile.

Regulatory and Translational Considerations

Patient-centric formulation must remain compatible with regulatory expectations for quality, safety and efficacy. For ODTs, FDA has specific guidance on the dosage-form designation and development considerations [5]. European pharmacopoeial requirements provide a defined disintegration expectation for orodispersible tablets [21]. For paediatric products, EMA guidance emphasizes pharmaceutical development, excipient safety, patient acceptability, dosing and administration considerations [3]. These frameworks reinforce the principle that patient needs should be addressed as part of product development rather than after formulation completion.

Translation from laboratory formulation to a marketable product requires reproducible manufacturing, scalable processes, appropriate packaging and stability under intended storage conditions. This is particularly important for moisture-sensitive ODTs, ODFs and effervescent formulations. Multiparticulate systems must maintain coating integrity during filling, compression and transport. Buccal systems must

maintain adhesion and drug release performance throughout shelf life. Advanced technologies may introduce additional regulatory complexity because changes in equipment, process parameters or raw materials can alter critical quality attributes.

Commercial success also depends on whether the patient perceives a meaningful advantage. A formulation that is technically novel but requires complex preparation, expensive packaging or inconvenient dosing may offer little real-world benefit. Conversely, a relatively simple formulation that eliminates water, reduces swallowing difficulty, improves taste or decreases dosing frequency may have substantial clinical value. Patient-centric formulation therefore requires an integrated assessment of technical performance, human factors, manufacturability, cost and therapeutic benefit.

Challenges and Research Gaps

One major research gap is the lack of standardized, universally accepted methods for measuring patient acceptability across dosage forms. Disintegration time is standardized more

readily than mouthfeel or palatability, while mucoadhesive strength measured on an artificial membrane may not directly predict human residence time. Similarly, an instrumental texture parameter may correlate with sensory perception under one formulation condition but not another. Greater harmonization between pharmaceutical testing and human-factor science is needed.

Another challenge is balancing multiple formulation objectives. Rapid disintegration can conflict with mechanical strength; taste masking can delay drug release; strong mucoadhesion can compromise comfort; high effervescence can increase moisture sensitivity; and extensive multiparticulate coating can increase manufacturing cost. These trade-offs support the use of QbD, multivariate optimization and patient-relevant decision criteria. Future studies should report not only formulation composition and in vitro results but also why the selected attributes matter to the intended users.

There is also a need for more evidence linking patient-centric dosage-form characteristics to clinical adherence and therapeutic outcomes. Patient preference studies, real-world adherence data, human-factor assessments and comparative clinical studies can strengthen the translational evidence base. In paediatrics, acceptability should be studied across age groups rather than assuming that a formulation acceptable to adults will be acceptable to children. Similar attention is required for older adults and patients with neurological or swallowing disorders.

Future Perspectives

The next generation of patient-centric formulations is likely to combine multiple technologies rather than rely on a single dosage-form innovation. Examples include taste-masked multiparticulate ODTs, buccal films containing nanosized drug carriers, effervescent systems with controlled release, and 3D-printed dosage forms combining immediate and modified-release compartments. Such hybrid systems can address several patient needs simultaneously, but their complexity must be justified by a measurable therapeutic or usability benefit.

Digital formulation development may further accelerate this transition. Artificial intelligence and machine learning can support prediction of

formulation performance, excipient compatibility and process outcomes, while digital manufacturing can enable individualized dose strengths and release profiles. However, data quality, model interpretability and process validation will determine whether these tools can move from laboratory demonstrations to regulated manufacturing. Patient preference data may also become a formal input into formulation optimization, allowing dosage forms to be designed around quantitative trade-offs between taste, size, dosing frequency and therapeutic performance.

A mature patient-centric development model should therefore follow a closed loop: identify patient needs, define the QTPP, translate needs into CQAs, select materials and manufacturing methods, optimize formulation using QbD, evaluate conventional and patient-relevant performance, verify usability with the target population, and continuously refine the product using real-world evidence. This approach transforms patient centricity from a descriptive concept into an actionable pharmaceutical development strategy.

Conclusion

Orodispersible, buccal, effervescent and multiparticulate formulations represent complementary strategies for addressing practical limitations of conventional oral dosage forms. Their value lies not simply in technological novelty but in their ability to solve defined patient problems such as swallowing difficulty, poor palatability, dosing inflexibility, need for water, high dosing frequency or inadequate drug exposure. ODTs and ODFs offer rapid and convenient oral administration; buccal systems provide opportunities for local and systemic mucosal delivery; effervescent formulations transform solid ingredients into rapidly dispersed preparations; and multiparticulates enable flexible dosing and sophisticated release control. The strongest future opportunities will come from integrating these platforms with patient-focused development, QbD, advanced manufacturing and systematic acceptability assessment. Formulation scientists should therefore move beyond the conventional definition of a successful dosage form as one that passes pharmacopoeial tests and

instead develop products that patients can comfortably, correctly and consistently use in real life.

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