Enhancing Bioavailability And Patient Adherence: A Review Of Modern Antiviral Drug Formulation Strategies

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Abstract

Viral infections such as influenza, herpes, hepatitis, and COVID-19 continue to affect millions of people worldwide. Antiviral drugs play a key role in slowing viral replication and reducing disease severity. [11].Among the available dosage forms, oral solid formulations—such as tablets, capsules, and powders—are preferred because they are easy to use, stable, and suitable for large-scale production. However, creating effective oral antivirals is challenging due to issues like poor solubility, instability, and low bioavailability.[12],[13],[15]

This review focuses on commonly used antiviral drugs, their mechanisms of action, and the strategies used in designing effective oral dosage forms. The study also highlights excipient selection, manufacturing techniques, quality control, regulatory guidelines, and emerging innovations like nanoparticles and long-acting systems. Together, these advancements aim to improve treatment effectiveness, patient adherence, and global access to antiviral therapy. [1], [4], [5].

Keywords: Antiviral drugs, Oral solid formulations, Tablets, Capsules, , Bioavailability

1. Introduction

Viruses cause a wide range of diseases, from mild infections to severe life-threatening illnesses. Over the past two decades, antiviral therapy has become more advanced, especially during outbreaks like COVID-19.[2],[4]. Most antiviral drugs are designed to block specific steps of the viral life cycle such as entry, replication, protein processing, or release.[1]

Oral antiviral drugs are especially important because:

- They can be taken at home
- They reduce hospital burden
- They are easy to distribute globally
- They improve patient compliance[3],[4],[10]

Examples such as **Oseltamivir**, **Acyclovir**, **Valacyclovir**, **Molnupiravir**, and **Paxlovid** show how essential oral therapies are in treating large populations.[9],[17]

Children require special formulations such as dry syrups, dispersible tablets, and flavored suspensions because they often cannot swallow tablets.

Modern antiviral formulation aims to solve challenges like low bioavailability, poor solubility, moisture sensitivity, and patient adherence issues.

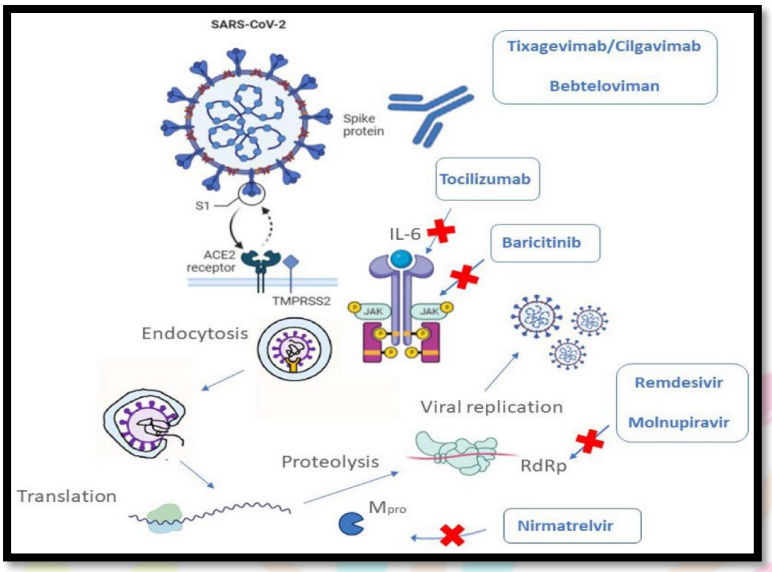

Figure 1 Antiviral Drug Therapy.

Polymerase inhibitors are used to treat coronavirus and influenza infections by interfering with viral RNA or DNA polymerases, which are essential for replication. Biologics are a more recent type of antiviral drugs that include interferons and monoclonal antibodies.[18].These treatments provide precise and powerful antiviral effects by focusing on certain viral proteins or immune system components. Monoclonal antibodies, for instance, have been created to destroy SARS-CoV-2, the virus that causes COVID-19,[14]providing patients with tailored therapy choices. Oral communication has advanced significantly during the last 20 years.[17].

Pediatric issues are crucial in antiviral medication since children are susceptible to a variety of viral illnesses. In order to provide safe and efficient dosing in younger populations, oral tablets, capsules, and powders for reconstitution are especially crucial for outpatient and pediatric care.[19] The goal of ongoing studies and clinical trials is to improve these formulations for children's safety, effectiveness, and acceptance. [16],[21]

The primary objective of modern formulation science is to overcome barriers such as poor water solubility, low oral bioavailability, high dosing requirements, and moisture sensitivity [16], [17].

Antiviral drugs act by targeting specific stages of the viral life cycle, thereby preventing replication, assembly, or release of viral particles.[20]. Understanding these mechanisms is crucial not only for selecting appropriate therapy but also for optimizing drug formulation, route of administration, and pharmacokinetic properties.[22] The major mechanisms of antiviral action can be categorized as follows:

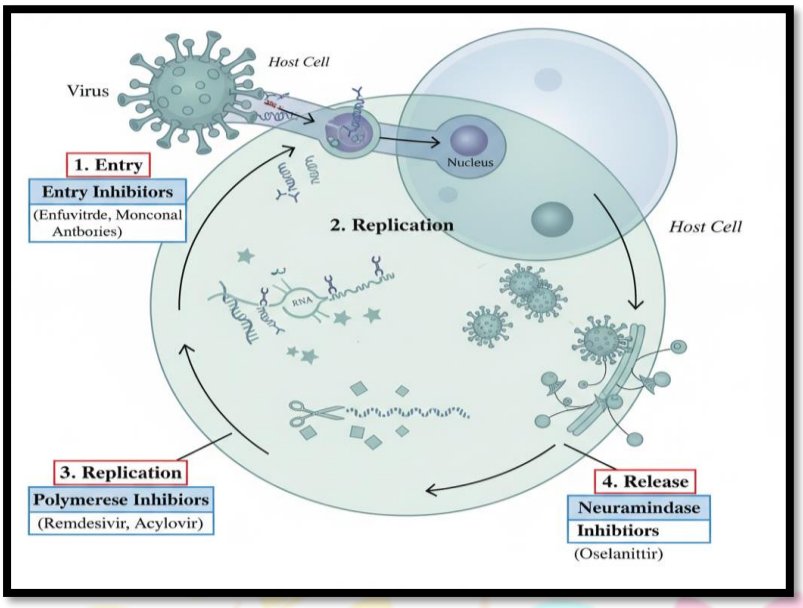

Figure 2 Mechanism of Action of Major Classes of Antiviral Drugs

Antiviral strategies are categorized into several mechanisms:

(a) Inhibition of viral entry or fusion, where drugs like enfuvirtide and monoclonal antibodies prevent viruses from entering host cells.[9]

(b) Inhibition of viral polymerases using nucleoside analogues such as acyclovir and remdesivir, which disrupt genome replication[7]

(c) Protease inhibition with drugs like lopinavir and ritonavir, preventing maturation of infectious virions[5]

(d) Neuraminidase inhibition, exemplified by oseltamivir, blocking the spread of influenza viruses; and (e) Capsid or assembly inhibitors that disrupt viral particle formation through targeting structural proteins. Each category employs unique formulation considerations to enhance efficacy and patient compliances[23]

Representative antiviral drugs and marketed oral dosage forms

The development of oral antiviral formulations must consider efficacy, bioavailability, patient compliance, stability, and population-specific needs, such as pediatric therapy. Below is a systematic overview of representative antiviral drugs and their marketed oral dosage forms

Drug	Dosage Form	Target Virus	Key Challenge	Solution Technology
Oseltamivir	Capsule / Powder	Influenza	Stability	Dry-powder tech
Valacyclovir	Tablet	HSV / VZV	Poor solubility	Prodrug design
Molnupiravir	Tablet	SARS-CoV-2	Rapid absorption	Solid dispersion

Table 1 : Examples of Marketed Oral Antivirals and Their Formulations

Oseltamivir (Tamiflu) is available as hard gelatin capsules and oral suspension, primarily for influenza treatment and prophylaxis, with the suspension being crucial for pediatric patients. Acyclovir and Valacyclovir (Valtrex) come in tablets and oral suspensions, treating herpes infections, with Valacyclovir designed for better absorption. Direct-acting antivirals (DAAs) for Hepatitis C are mainly oral tablets targeting viral proteins to ensure effectiveness. SARS-CoV-2 oral antivirals like Molnupiravir and Nirmatrelvir/Ritonavir (Paxlovid) are tablets aimed at outpatient use to prevent severe disease, designed for ease of distribution and adherence, supported by WHO and FDA guidelines.

2. Literature Review (2020–2025)

Recent studies from 2020–2025 highlight major progress in antiviral therapies. During the COVID-19 pandemic, significant focus was placed on oral antivirals such as Molnupiravir and Nirmatrelvir/Ritonavir, which helped reduce hospitalization rates. Research also expanded into nanoparticle-based carriers, mucoadhesive drug delivery, and improved solid dispersion techniques to enhance bioavailability. Several studies demonstrated the importance of pediatric-friendly formulations, including dry syrups and dispersible tablets. Publications further emphasized the need for stability improvements, regulatory alignment, and patient adherence strategies.

Literature Review (2020–2025)

Year	Author / Study	Key Focus	Findings / Contribution	Relevance to Current Study
2020	Parums et al. (2020–COVID period)	Early antiviral strategies & repurposed drugs	Highlighted limitations of existing oral antivirals during pandemic; need for faster-acting drugs	Shows gaps in oral antiviral formulations and urgency for improvement
2021	Kausar (2021)	Mechanisms of antiviral drugs	Detailed mechanisms like polymerase inhibition, protease inhibition, and viral entry inhibition	Helps understand why certain antivirals require specific formulation types
2021	WHO Clinical Updates	COVID-19 antiviral recommendations	Documented challenges in oral dosage distribution, stability, and patient adherence	Supports the importance of stable oral formulations
2022	Rahmah (2022)	Oral antivirals for SARS-CoV-2	Reported on Molnupiravir & Paxlovid effectiveness in outpatient care; improved patient adherence	Strong evidence for need of oral, fast-acting, stable formulations
2022	Parums (2022)	Improved drug	Discussed	Reinforces need for

Year	Author / Study	Key Focus	Findings / Contribution	Relevance to Current Study
		delivery for COVID-19	bioavailability challenges, high-dose issues, and new delivery approaches	solubility enhancement and dose optimization
2023	Pharmaceutical Tech Review (2023)	Solid dispersion & nanoparticle systems	Found increased solubility and dissolution rate in poorly soluble antivirals	Supports using solid dispersions and nano systems in tablets and capsules
2023	Pediatric Formulation Studies	Child-friendly dosage forms	Dry syrups, dispersible tablets, flavored suspensions improved acceptance	Relevant to powders-for-reconstitution section of your paper
2024	Gupta (2024)	Advanced antiviral formulation methods	Reported enhancements through hot-melt extrusion & polymeric carriers	Confirms importance of modern techniques in improving oral bioavailability
2024	FDA (2024) M13 Bioequivalence Guideline	Regulatory requirements	Emphasized dissolution standards, stability, and bioequivalence for immediate-release forms	Directly relevant to regulatory part of your research
2025	Recent Innovations Review (2025)	Nanocarriers + mucoadhesive systems	Showed improved GI retention & controlled release in antiviral therapy	Suggests future direction for improved antiviral performance

Table 2 : Research Study From 2020 to 2025

3. Methodology

This review paper uses a narrative research methodology. Data was collected from peer-reviewed journal articles, regulatory documents, science-direct publications, and WHO/FDA updates between 2020 and 2025. The reviewed literature includes clinical trials, formulation studies, pharmacokinetic evaluations, and technological advancements in antiviral drug delivery. All sources were analyzed for relevance, scientific accuracy, and contribution to modern formulation improvements.[21]

4. Limitations of the Research

This study is limited to published literature available between 2020 and 2025. No primary laboratory experiments were conducted. Some recent innovations may not yet be published in accessible databases[19].

Additionally, differences in regulatory guidelines across countries may impact formulation outcomes, and these variations are not fully represented in this review.

5. Future Scope

Future research should focus on developing long-acting oral antivirals, enhancing nanocarrier technologies, and improving bioavailability for poorly soluble drugs. Pediatric formulations require more innovation, especially for low-resource settings. Digital-health-supported adherence systems may improve patient outcomes. Further work is also needed to integrate AI-based predictive models into formulation design and optimize stability of reconstitutable antiviral powders.

Conclusion

Oral antiviral drugs remain essential in global healthcare. Tablets, capsules, and powders offer ease of use, stability, and cost-effectiveness. However, challenges such as poor solubility and low bioavailability require advanced formulation strategies.
Techniques such as solid dispersions, nanoparticles, lipid systems, and improved excipients have shown strong potential in enhancing antiviral drug performance.
With continued research, regulatory support, and innovative delivery systems, antiviral formulations will become more effective, accessible, and patient-friendly in the coming years.

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