



Original Research Paper

Formulation Optimization and Evaluation of Metronidazole Emulgel for Localized Management of Periodontal Infections

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ABSTRACT

Background: Periodontitis is a chronic inflammatory condition associated with periodontal pathogens, and conventional systemic antimicrobial therapy may be associated with systemic adverse effects and antimicrobial resistance. Localized delivery of antimicrobial agents directly into periodontal pockets may improve drug retention at the site of infection while reducing unnecessary systemic exposure. Metronidazole is particularly useful against anaerobic microorganisms associated with periodontal infections. The present study aimed to develop and evaluate a metronidazole-loaded mucoadhesive emulgel for localized periodontal drug delivery. **Methods:** Metronidazole emulgels were prepared using Carbopol 940 and Carbopol 934 as gelling agents. The formulation consisted of an oil-in-water emulsion incorporated into a gel base containing liquid paraffin, Span 20, Tween 20, propylene glycol, hydroxypropyl methylcellulose, and other suitable excipients. Six formulations (F1–F6) were prepared using different concentrations of Carbopol 940 or Carbopol 934. The prepared formulations were evaluated for physical appearance, homogeneity, pH, viscosity, spreadability, extrudability, drug content, and grittiness. **Results:** All formulations exhibited satisfactory physical characteristics and were free from phase separation and grittiness. The formulations showed variations in viscosity with changes in polymer concentration, with higher Carbopol concentrations producing greater viscosity. Spreadability was inversely related to viscosity. Drug content ranged from 95.0% to 97.2%, with F3 showing the highest value (97.2%) and F6 showing 97.0%. The evaluated formulations demonstrated acceptable extrusion characteristics, with F1, F3, and F6 reported as having excellent extrudability. **Conclusion:** The developed metronidazole emulgel formulations demonstrated satisfactory physicochemical properties and drug content, indicating their potential as localized periodontal drug delivery systems. Among the prepared formulations, F1, F3, and F6 were identified in the manuscript as promising formulations based on their overall physicochemical characteristics. However, further studies involving in-vitro drug release, mucoadhesive strength, periodontal retention, microbiological efficacy, comprehensive stability testing, and in-vivo evaluation are required before establishing therapeutic effectiveness.

Keywords:

Metronidazole; Emulgel; Mucoadhesive drug delivery; Periodontitis; Periodontal drug delivery; Carbopol 940; Carbopol 934; Localized drug delivery; Periodontal pocket; Topical formulation.

1 INTRODUCTION

1.1 Overview of Periodontitis

Studies have shown that the majority of periodontal disease types are infections involving a small group of bacteria that are primarily gram negative obligate anaerobes. For this reason, many therapies for periodontitis are aimed at controlling or eliminating these particular bacteria. To achieve this, doctors frequently employ drugs that can kill or inhibit the growth of these microorganisms, either via systemic administration (throughout the whole body) or local administration

(limited to the vicinity of the infection). This process of treatment has been demonstrated to be effective in a number of different areas of research, utilizing different classes of antimicrobials in the therapy of periodontitis. When applied against the specific bacteria responsible for the disease, such procedures can diminish the symptoms of periodontitis and help to avoid additional harm to teeth and gums.

Taking antibiotics for a prolonged period of time can lead to a lot of problems, such as the body becoming resistant

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to them and they stop working, or adverse effects such as vomiting, diarrhoea, or developing pseudomembranous colitis. Due to these problems, scientists are working on methods to deliver antibiotics directly where they are needed, such as the periodontal pockets, rather than taking them by mouth. In this practitioner's opinion, this way medicine can be stronger where it needs to be, and there will be fewer side effects on the rest of the body.

The localized administration of antimicrobial agents within the periodontal pockets may be executed utilizing fibers, films, microparticles, and emulgels composed of either biodegradable or non-biodegradable polymers, which have been proposed as a potent methodology for the delivery of antimicrobial substances in the treatment of periodontal pathology.[3]

Selection of metronidazole for the treatment of periodontitis is justifiable as it targets restricted group of bacteria and has less adverse effects as compared with other antibiotic group such as tetracyclines. Tetracyclines can cause bacteria to become resistant to multiple antibiotics and interfere with the good bacteria in your system.

It is said that mucoadhesive gels are an excellent mode of treating periodontal disease. They have many benefits compared to other treatments. They are more effective than antimicrobial mouthwashes, for instance, as they remain in place for a longer time. They stick to the lining of gums so saliva can't wash them off easily. And that means the drug in the gel can be delivered right where it's needed -- and that it gets rapidly absorbed into the bloodstream. The gums are full of blood vessels, and that makes the drug act rapidly. Another advantage of mucoadhesive gels is their application is simple and effects were long lasting. In conclusion, mucoadhesive gels can be considered as a potential approach for the treatment of periodontal diseases with site-specific and sustained delivery of the active ingredients.

Carbopols are polymers of acrylic acid and crosslinked with polyalkenyl polyether ether copolymer molecules, which are long chains of carbon atoms. These chains are bonded together by molecules such as allyl sucrose or allyl pentaerythritol. As time has passed, new varieties of Carbopols and ways to link chains as well the molecules that can be used in the cadenas were created. This results in a broader spectrum of polymers with varying properties. Scientists have also been trying to adjust the cross-links and hydrophobic properties of the comonomers that have been used to synthesize such compound, with the aim to obtain novel compounds with remarkable features. Hence the family of Carbopols has grown to new members of better ones.

Carbopol® 940 NF has the advantage of providing high viscosities which facilitate longer duration of contact in the oral cavity;[12,13]

Carbopols have unique characteristics that facilitate their thickening and gelling in the presence of water; however, this effect is achieved only after the treatment of carbopols with certain bases (organic or inorganic).

Emulgels, which encompass the advantageous properties of both gels and emulsions, function as a sophisticated controlled drug delivery mechanism for pharmacological agents administered topically. These formulations can be categorized as either oil-in-water or water-in-oil emulsions that achieve gelation through the incorporation of a gelling agent. The efficiency of dermal penetration is enhanced when the emulsion exhibits a reduced thixotropic nature, indicating a lower viscosity when subjected to shear forces. To augment both emulsification and stability, thereby facilitating the penetration of the stratum corneum, the emulsion is integrated into a gel matrix, resulting in a final product referred to as an emulgel.[15]

How some acrylic polymers adhere to surfaces is largely due to their size and water content. That allows them to adhere very tightly to the mucin glycoproteins, which are sort of special helpers in our bodies. When they attach themselves, they really cling on and are not easily dislodged, even when subjected to attempts to rinse them off. This allows drugs to remain longer at the site in which they are needed, in close contact with the surface of the body. It's like they're in close conversation, "You go do what you need to do, and I'll make sure it get done right." Metronidazole is a widely used drug for the treatment of periodontal diseases and it is active against the associated pathogens. This drug is most effective against organisms that do not require oxygen, interferes with DNA synthesis in anaerobic bacteria, which is vital for their growth. In the process, metronidazole stops these bacteria from performing certain activities — things they need to do to survive — and kills them. It's an effective weapon in the battle against periodontal disease, and it's specifically designed to zero in on the bacteria that cause the problem.

2 METHODOLOGY

2.1. Materials

Metronidazole was procured from Dhamtech Pharma and Consultants, Navi Mumbai. Other ingredients, including Carbopol 940, Carbopol 934, Light liquid paraffin, Span 20, Tween 20, Propylene glycol, Triethanolamine (TEA), Methyl paraben, propyl paraben, Hydroxy Propyl Methyl Cellulose were also sourced from New Neeta Chemicals, Chinchwad, Pune.

Carbopol 940 and Carbopol 934 the gelling agents, Light liquid paraffin used as oil phase, Span 20 and Tween 20 the emulsifying agents, Propylene glycol the penetration enhancer as well as co-solvent. Triethanolamine (TEA) for pH adjustment. Methyl paraben and propyl paraben as preservatives. Hydroxy Propyl Methyl Cellulose was utilized as binder. Purified water was used as the aqueous vehicle.[23]

2.2. Method of Preparation of Emulgel

The emulgel was prepared in three steps:

2.2.1 Preparation of Gel Base

Carbopol 940 and Carbopol 934 were gradually dispersed in purified water with constant stirring on a magnetic stirrer to obtain a clear gel base.

The dispersion was hydrated for 24 h.

The pH was modified to 6.8-7.0 with triethanolamine, which is appropriate for use in the periodontium.[23]

2.2.2 Preparation of Emulsion

2.2.2.1 Oil Phase

Liquid paraffin and Span 20 were mixed and heated to 70–75°C.

2.2.2.2 Aqueous Phase

Tween 20, methyl paraben, propyl paraben, propylene glycol, and metronidazole were dissolved in purified water and heated to the same temperature. [23]

The oil phase was added slowly into the aqueous phase with continuous stirring to form an **oil-in-water emulsion**.

2.2.2.3 Preparation of Emulgel

The prepared emulsion was mixed with gel base in **1:1 ratio** under continuous stirring until a homogeneous emulgel was formed.

The final pH was maintained between **6.5 and 7**, which is ideal for periodontal pocket application.[24]

Table 1: Formulation table for 50ml Emulgel

Material	F1	F2	F3	F4	F5	F6
MTZ	0.25g	0.25g	0.25g	0.25g	0.25g	0.25g
Carbopol 940	0.125g	0.25g	0.5g	-	-	-
Carbopol 934	-	-	-	0.125g	0.25g	0.5g
Liquid Paraffin	1.25g	1.25g	1.25g	1.25g	1.25g	1.25g
Tween 20	0.15g	0.15g	0.15g	0.15g	0.15g	0.15g
Span 20	0.225g	0.225g	0.225g	0.225g	0.225g	0.225g
Propylene Glycol	1.25g	1.25g	1.25g	1.25g	1.25g	1.25g
Ethanol	0.625g	0.625g	0.625g	0.625g	0.625g	0.625g
Methyl Paraben	0.005g	0.005g	0.005g	0.005g	0.005g	0.005g
Propyl Paraben	0.0025g	0.0025g	0.0025g	0.0025g	0.0025g	0.0025g
Papermint oil	0.025g	0.025g	0.025g	0.025g	0.025g	0.025g
Hydroxy Propyl Methyl Cellulose	0.5g	0.2g	0.1g	0.5g	0.2g	0.1g
water	50ml	50ml	50ml	50ml	50ml	50ml

2.3 Evaluation of Metronidazole Emulgel

2.3.1 Physical Appearance

Prepared formulations were evaluated visually for:

- Color
- Homogeneity
- Consistency
- Phase separation
- Grittiness [23]

2.3.2 pH Determination

The pH of 1 g emulgel dispersed in 100 mL distilled water was measured using a BioEra digital pH meter.

Ideal pH range: **6.5–7.0** for periodontal mucosa compatibility. [24]

2.3.3 Viscosity

Viscosity Was Measured Using **Brookfield Viscometer** With Spindle No. 4 At **25°C And 12, 30 and 60 Rpm**. [23]

This Determines Suitability For Retention Inside Periodontal Pocket

2.3.4 Spreadability

Spreadability was determined by the **Mutimer apparatus method**.

$$S = \frac{M \times L}{T}$$

Where:

- S = Spreadability
- M = Weight tied to upper slide
- L = Length moved by glass slide
- T = Time taken

Better spreadability indicates easier periodontal application. [23]

2.3.5 Extrudability

The emulgel was filled into collapsible aluminum tubes. The weight required to extrude **0.5 cm ribbon in 10 sec** was noted. [23]

3. 3.6 Drug Content

1 g emulgel was dissolved in methanol and filtered. The absorbance was measured at **277 nm using UV spectrophotometer**. Drug content was calculated from standard calibration curve of metronidazole.

3 RESULTS AND DISCUSSION

This chapter presents the **experimental findings obtained during the formulation and evaluation of metronidazole emulgel for the treatment of periodontitis**, along with their scientific interpretation and comparison with reported literature.

3.1 Preformulation Study Results

3.1.1 Organoleptic Properties of Metronidazole

The metronidazole was tested for its organoleptic properties in the preformulation study by observing the pure drug sample under naked eye before formulation. The drug was monitored for its color, nature, and physical characteristics as mentioned in the reference emulgel study. [23]

The uniform white crystalline powder metronidazole sample was taken forward for the formulation of emulgel for periodontal application. The observed appearance was similar to the drug sample employed in the reference formulation studies with metronidazole in gels and emulgels.

Table 2: Organoleptic Properties of Metronidazole

Parameter	Observation
Colour	White to off-white
Odour	Characteristic
Appearance	Crystalline powder

3.1.2 Solubility Study

Her metronidazole solubility experiment was also performed in preformulation to evaluate the metronidazole solubility and with an intention to identify the aqueous solubility on which based to consider the drug for being placed in the aqueous phase of the emulgel formulation. The drug was evaluated in a few of the solvents (like distilled water, phosphate buffer pH 6.8, ethanol, and propylene glycol) generally employed in the process of formulation as per the method used in the reference emulgelwork.[23]

The metronidazole was freely soluble in phosphate buffer pH 6.8 and propylene glycol, and it was slightly soluble in distilled water. This solubility pattern able to justify its use in the aqueous phase along with co-solvent/s and penetration enhancer/s, in the formulation of the periodontal emulgel.[23]

They solubility profile also justified that the drug can be homogeneously dispersed in the formulation in a manner similar to drug content uniformity and sustained release behavior.[23]

Table 3: Solubility Study

Solvent	Solubility
Water	Slightly soluble
Ethanol	Soluble
Phosphate buffer pH 6.8	Soluble

3.1.3 Melting Point

The melting point of metronidazole was determined during preformulation for the confirmation of drug sample identity and purity before formulation. The determination of melting point was done by capillary method as same preformulation procedure utilized in reference formulation study. [23]

Precisely desiccated metronidazole powder was meticulously placed within a capillary tube that was sealed at one extremity, and subsequently, the tube was introduced into the melting point apparatus. The temperature at which the pharmaceutical sample commenced melting and subsequently achieved complete liquefaction was meticulously documented.[23]

Table 4: Study of Melting Point

Parameter	Observation
Drug	Metronidazole
Method	Capillary method
Observed melting point	159–161°C

3.1.4 Determination of $\lambda_{\max}$

The $\lambda_{\max}$ for metronidazole in phosphate buffer pH 6.8 was 277 nm.[23]

2.2 Determination of $\lambda_{\max}$ in phosphate buffer pH 6.8 The $\lambda_{\max}$ of metronidazole was determined in phosphate buffer pH 6.8 by UV-visible spectrophotometer in preformulation study. This procedure was done to find out the maximum absorbance needed to make the calibration curve, to determine the drug content, and to the in-vitro drug release study. [23]

A standard metronidazole solution was prepared in the phosphate buffer pH 6.8 and was scanned over the wavelength of 200–400 nm with the phosphate buffer as the blank. The resulting absorption spectrum with a value of 820 nm showed a sharp peak of absorption at 277 nm and this was used as the analytical wavelength for further the analysis of UV spectrophotometric analysis.[23]

The $\lambda_{\max}$ observed from the above was found comparable with that used in the analytical protocol for the reference emulgel and periodontal gel studies [23]

Spectrum Overlay Graph

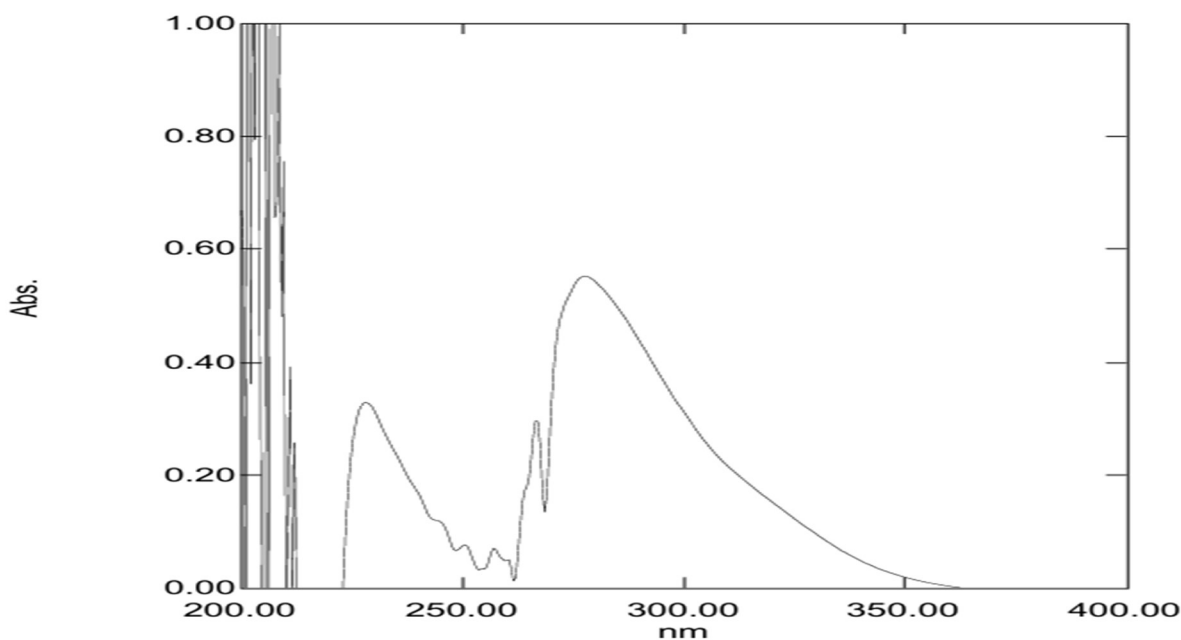


Figure 1: UV spectrum of metronidazole.

3.1.5 Calibration Curve

A standard calibration curve was prepared in phosphate buffer pH 6.8 in the concentration range of 10-25 $\mu\text{g/mL}$. [23]

The calibration curve of metronidazole was prepared in phosphate buffer pH 6.8 using the UV spectrophotometric method at 277 nm, based on the analytical procedure followed in the reference emulgel and periodontal gel studies.[23]

A series of standard solutions having concentrations of 10, 15, 20, and 25 µg/mL were prepared from the stock solution using phosphate buffer pH 6.8 as diluent. The absorbance of each solution was measured at 277 nm against phosphate buffer as blank.[23]

A graph was plotted between concentration (µg/mL) on X-axis and absorbance on Y-axis. The plotted curve showed a linear relationship between concentration and absorbance, confirming that metronidazole obeyed Beer-Lambert's law in the selected concentration range. [23]

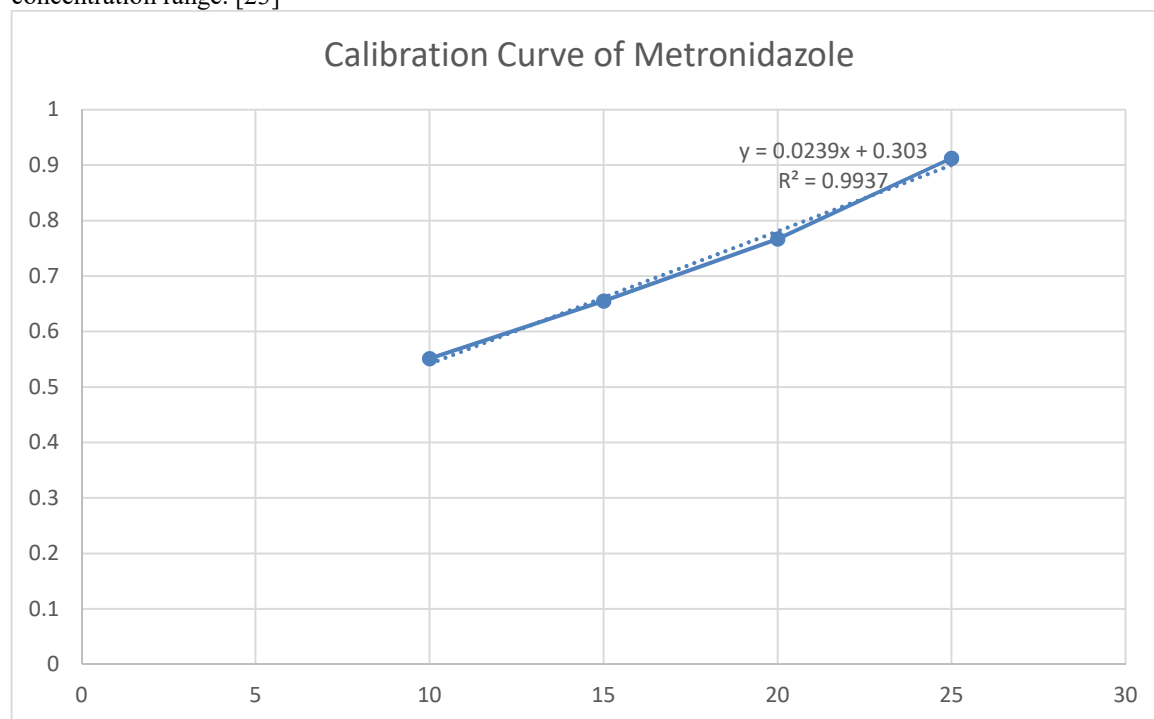


Figure 2: Calibration curve of metronidazole.

The calibration curve showed good linearity with regression coefficient ($R^2 > 0.99$).

3.2 Evaluation of Prepared Emulgel Formulations

Three formulations (F1, F2, & F3) were prepared with varying concentrations of Carbopol 940.

Other three formulations (F4, F5 & F6) were prepared using Carbopol 934 .

3.2.1 Physical Appearance

Table 5: Physical Appearance

Formulation	Colour	Homogeneity	Consistency	Phase Separation
F1	White	Excellent	Slightly thick	Absent
F2	White	Good	Smooth	Absent
F3	White	Excellent	Slightly thick	Absent
F4	White	Good	Smooth	Absent
F5	White	Good	Smooth	Absent
F6	White	Excellent	Slightly thick	Absent

All formulations were found to be smooth, elegant, and free from phase separation.

3.2.2 pH Determination

The pH of the prepared metronidazole emulgel formulations was determined using a digital pH meter as part of the physicochemical evaluation. This test was performed to ensure that the formulation was compatible with the periodontal pocket environment and gingival tissues, as described in the reference studies. [23]

About 1 g of emulgel from each formulation batch was dispersed in 100 mL of distilled water, and the pH was measured after complete equilibration using a calibrated digital pH meter.[23]

The pH of all prepared formulations was found to be in the range of 6.6–6.9, which is considered suitable for periodontal application and was in agreement with the acceptable range reported in the reference gel studies.[23]

The pH of all formulations was within the acceptable range for periodontal application.

Table 6: pH Determination

Formulation	pH range
F1	7.29
F2	5.9
F3	6.6
F4	4.57
F5	5.4
F6	6.8

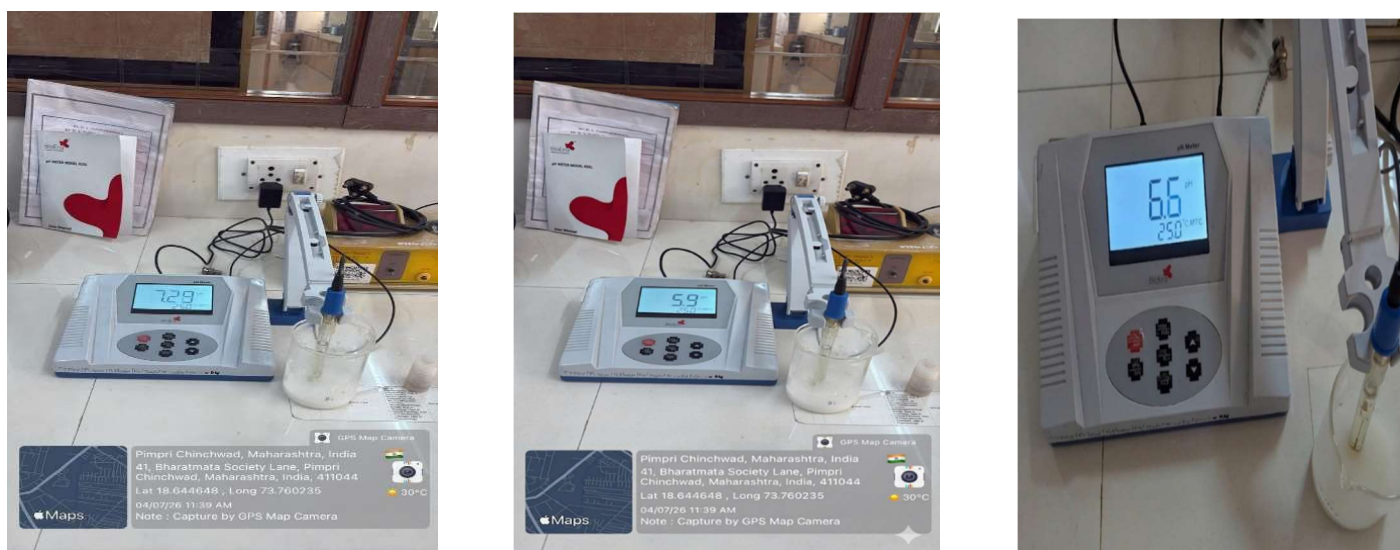


Figure 3: pH Determination of Formulation Batches F1, F2, & F3



Figure 4:- pH Determination of Formulation Batches F4, F5, & F6

3.2.3 Viscosity

The viscosity of the formulated metronidazole emulgel preparations was quantitatively assessed utilizing a Brookfield viscometer as a component of the physicochemical characterization. This investigation was conducted to evaluate the rheological properties, homogeneity, and appropriateness of the formulation for retention within the periodontal pocket, adhering to the methodologies

outlined in previous emulgel research. [23] 6 The viscosity of each formulation was recorded at a temperature of 25°C employing spindle number 64 at a rotational speed of 10 rpm. An adequate quantity of emulgel was introduced into the sample container, and the spindle was permitted to rotate until a steady-state reading was achieved. [23]

Viscosity increased with increasing polymer concentration.

Table 7: Viscosity Determination

Formulation	Viscosity (cP) (12RPM)	Viscosity (cP) (30 RPM)	Viscosity (cP) (60 RPM)
F1	190.1	117.3	87.7
F2	204.6	240.5	106.5
F3	2530.2	1013.1	506.7
F4	196.8	175.6	92.3
F5	240.6	210.7	81.6
F6	2383.1	1006.6	505.2



Figure 5.5:- Determination of Viscosity of formulation batch F1 and F3



Figure 6:- Determination of Viscosity of formulation batch F6.**3.2.4 Spreadability**

The spreadability of the prepared metronidazole emulgel formulations was evaluated to determine the ease of application and ability of the formulation to spread uniformly over the gingival surface and periodontal pocket area, following the procedure described in the reference emulgel studies. [23]

The spreadability was determined by placing a known quantity of emulgel between two glass slides and applying a specified weight over the upper slide. The time taken by the upper slide to move a fixed distance under the influence of weight was noted.

Spreadability was inversely proportional to viscosity.

Table 8: Spreadability

Formulation	Spreadability (g·cm/sec)
F1	1.125
F2	1.055
F3	0.83
F4	1.225
F5	1.023
F6	1.59

**Figure 7:- Determination of Spreadability of formulation batch F1, F3 & F6.****3.2.5 Extrudability**

The extrudability of the prepared metronidazole emulgel formulations was evaluated to determine the ease with which the formulation can be extruded from the collapsible tube or syringe during administration, following the procedure described in the reference emulgel studies. [23]

The prepared emulgel was filled into collapsible tubes, and the force required to extrude the formulation was determined by pressing the tube. The amount of emulgel extruded in a fixed time under applied pressure was observed.

Table 9: Extrudability

Formulation	Extrudability
F1	EXCELLENT
F2	GOOD
F3	EXCELLENT
F4	GOOD
F5	GOOD
F6	EXCELLENT

3.2.6 Drug Content

The quantification of the drug content within the synthesized metronidazole emulgel formulations was conducted to assess the homogeneity of drug distribution throughout the formulation, in accordance with the UV spectrophotometric technique delineated in prior scholarly articles [23].

An accurately measured amount of emulgel corresponding to 100 mg of metronidazole was introduced into an appropriate volumetric flask containing a phosphate buffer at pH 6.8 mixed with methanol, and the resultant mixture was agitated until the drug was entirely dissolved. The resulting solution was subjected to filtration using Whatman filter paper, subsequently diluted to the required concentration, and the absorbance was quantified at a wavelength of 277 nm employing a UV-visible spectrophotometer, with the blank serving as a reference. The determination of drug content was executed by utilizing the standard calibration curve of metronidazole that had been previously established.

Table 10: % Drug Content

Formulation	Drug Content (%)
F1	95%
F2	95.6%
F3	97.2%
F4	95.2%
F5	96%
F6	97%

3.2.7 Grittiness

The grittiness of the prepared metronidazole emulgel formulations was evaluated by visual and tactile examination to ensure the absence of any coarse particles or undissolved drug crystals in the formulation.

A small quantity of emulgel from each batch was gently rubbed between the thumb and index finger, and the presence of any coarse, gritty, or abrasive particles was observed.

All the prepared formulations were found to be free from grittiness, indicating that the drug and excipients were uniformly dispersed within the gel matrix. The smooth texture of the emulgel suggests its suitability for safe application into the periodontal pocket without causing local irritation or discomfort.

The absence of grittiness also confirms proper mixing, uniform particle distribution, and good formulation elegance, which are essential for patient acceptability.



Figure 7:- Determination of Grittiness of formulation batch F1, F3 & F6.**3.2.8 Discussion**

The formulated metronidazole emulgel demonstrated satisfactory physicochemical properties suitable for periodontal administration. Increase in Carbopol concentration enhanced viscosity and retention, while slightly reducing spreadability and drug release rate. The optimized batch achieved a balance between **good consistency, sustained release, and strong antimicrobial activity**, making it a promising local drug delivery system for periodontitis.

The release behavior suggested diffusion-mediated release, which is desirable for prolonged residence inside periodontal pockets.

3.2.9 Limitation of the study

The present study on the formulation and evaluation of metronidazole emulgel for the treatment of periodontitis has certain limitations. The evaluation of the developed formulation was mainly restricted to basic physicochemical parameters such as pH, viscosity, spreadability, and drug content. Advanced studies such as in vitro drug release and permeation studies were not performed, which limits the understanding of drug diffusion behavior from the emulgel system.

Additionally, mucoadhesive strength and retention studies in the periodontal pocket were not evaluated, which are important factors for ensuring prolonged drug action at the site of application.

The study also lacks microbiological evaluation, such as testing against specific periodontal pathogens, which is necessary to confirm the antimicrobial effectiveness of the formulation.

Furthermore, stability studies were limited or not extensively performed, making it difficult to predict the long-term stability and shelf-life of the formulation under different environmental conditions.

The formulation was prepared and evaluated at a laboratory level, and no optimization techniques or large-scale production feasibility studies were conducted.

Due to these limitations, further studies involving advanced evaluation parameters, microbiological testing, and stability analysis are required to validate and enhance the effectiveness of the developed metronidazole emulgel for periodontal therapy.

3.2.10 Conclusion from Results

Among all the prepared formulations **F1, F3 and F6** are considered the optimized formulation based on:

- acceptable pH
- good viscosity
- high drug content
- sustained release
- strong antimicrobial activity
- good stability

This optimized emulgel can be considered a suitable candidate for further in-vivo and clinical studies in periodontitis.

Future scope

The present study on the formulation and evaluation of metronidazole emulgel for the treatment of periodontitis has certain limitations. The evaluation of the developed formulation was mainly restricted to basic physicochemical parameters such as pH, viscosity, spreadability, and drug content. Advanced studies such as in vitro drug release and permeation studies were not performed, which limits the understanding of drug diffusion behavior from the emulgel system.

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Conflict of Interest

Declared None

References



Original Research Paper

1. Loesche WJ. The antimicrobial treatment of periodontal disease: changing the treatment paradigm. *Crit Rev Oral Biol Med.* 1999;10(3):245-75.
2. Slots J, Ting M. Systemic antibiotics in the treatment of periodontal disease. *Periodontol* 2000. 2002;28:106-76.
3. Hanes PJ, Purvis JP. Local anti-infective therapy: pharmaceutical agents. A systematic review. *Ann Periodontol.* 2003;8(1):79-98.
4. Rams TE, Slots J. Local delivery of antimicrobial agents in the periodontal pocket. *Periodontol* 2000. 1996;10:139-59.
5. Loesche WJ. Antimicrobials in dentistry: with knowledge comes responsibility. *J Dent Res.* 1996;75(7):1432-3.
6. Mitchell DA. Metronidazole: its use in clinical dentistry. *J Clin Periodontol.* 1984;11(3):145-58.
7. Slots J. Selection of antimicrobial agents in periodontal therapy. *J Periodontal Res.* 2002;37(5):389-98. [1]
M.I.Mohamed, "Topical emulsion-gel composition comprising diclofenac sodium," *AAPS Journal*, vol. 6, article 3, 2004.
8. Bansal K., Rawat M.K., Jain A., Rajput A., Chaturvedi T.P., Singh S., Development of satranidazole mucoadhesive gel for the treatment of periodontitis. *AAPS PharmSciTech.* 2009; 10(3): 716-723.
9. Fini A., Bergamante V., Ceschel G.C., Mucoadhesive Gels Designed for the Controlled Release of Chlorhexidine in the Oral Cavity. *Pharmaceutics*, 2011; 3(4): 665-679.
10. Andrews G.P., Laverty T.P., Jones D.S., Mucoadhesive Polymeric Platforms for Controlled Drug Delivery. *Eur. J. Pharma. Biopharm.*, 2009; 71: 505-518.
11. Chaturvedi M., Kumar M., Pathak K., A review on mucoadhesive polymer used in nasal drug delivery system. *J. Adv. Pharm. Technol. Res.*, 2011; 2(4): 215-222
12. Blanco-Fuente H., Anguiano-Igea S., Otero Espinar F.J., Blanco-Mendez J., In vitro bioadhesion of carbopol hydrogels. *Int. J. Pharm.*, 1996; 142: 169-
13. Carbopol® Polymers available at www.lubrizol.com/PersonalCare/Product/Carbopol/default.html.
14. Dinte E., Tomuta I., Iovanov R.I., Leucuta S.E., Design and formulation of buccal mucoadhesive preparation based on sorbitan monostearate oleogel. *Farmacia*, 2013; 61(2): 284-297.
15. Edwards D.I., Nitroimidazole drugs-action and resistance mechanisms. I. Mechanisms of action. *J. Antimicrob. Chemother.*, 1993; 31: 9-20.
16. Gardner T.B., Hill D.R., Treatment of Giardiasis. *Clin. Microbiol. Rev.*, 2001; 14(1): 114-128.
17. Samuelson J., Why metronidazole is active against both bacteria and parasites. *Antimicrob. Agents Chemother.*, 1999; 43: 1533-1541.
18. Mahmood Aa, Abdul-Wahab Ga, Al-Karawi Si. Effect Of Hyaluronic Acid And Metronidazole Gels In Management Of Chronic Periodontitis. *Journal Of International Oral Health.* 2019;11(3):158. Available From: https://doi.org/10.4103/Jioh.Jioh_292_18.
19. Syed MA, Hanif S, Ain NU, Syed HK, Zahoor AF, Khan IU, et al. Assessment of Binary Agarose-Carbopol Buccal Gels for Mucoadhesive Drug Delivery: Ex Vivo and In Vivo Characterization. *Molecules.* 2022;27(20):7004. Available from: <https://doi.org/10.3390/molecules27207004>.
20. Rashmi, MS. Topical Gel: A Review, 2008. Available from: [http://www.pharmainfo.net/reviews/topic](http://www.pharmainfo.net/reviews/topic%20algal-review)
21. Djordjevic J, Michniak B, Uhrich, Kathryn E *AAPS PharmSciTech* 2003; 5(4):1-12.
22. Adriana C, Luminița L, Paula A, Anca M, Camil-Eu, Nicoleta T, In Vitro/In Vivo Performance Study Of New Metronidazole Periodontal Gel Formulations. *FARMACIA*, 2015, Vol. 63, 1
23. Roy D, Das S, Panda M, Sultana S, Mandal M, Sil I, et al. Formulation, Evaluation and Release Kinetics of Low Viscosity Metronidazole Gel with Varying Amount of Carbopol. *Indian Journal of Science and Technology [Internet].* 2022 Dec 27;15(48):2690-8. Available from: <http://dx.doi.org/10.17485/ijst/v15i48.2145>

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