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Formulation and evaluation of gastro retentive floating drug delivery system of Atenolol

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ABSTRACT
Drugs that have narrow absorption window in the gastrointestinal tract (GIT) will have poor absorption. For these drugs, gastro retentive drug delivery systems offer the advantage in prolonging the gastric emptying time. Atenolol is an antihypertensive drug, which has low elimination half-life: 3–4 hrs. The floating tablets of Atenolol were prepared to increase the gastric retention and to improve the bioavailability of the drug. Atenolol was chosen as a model drug because it is better absorbed in the stomach than the lower gastro intestinal tract. The rapid gastro-intestinal transit could result in incomplete drug release from the drug delivery system above the absorption zone leading to poor bioavailability of the drug. The floating tablets were formulated using HPMC K4M and HPMC K100M as the release retardant polymers, and sodium bicarbonate as the gas generating agent to reduce the floating lag time. The tablets were prepared by direct compression. The formulated tablets were evaluated for weight variation, hardness, friability, swelling index floating lag time, total floating time and dissolution rate in pH 1.2. The floating tablets extended the drug release up to 8 hrs. The drug-polymer interaction was evaluated by fourier transform infrared spectroscopy (FTIR). The FTIR study indicated the lack of drug-polymer interaction.

Keywords: Atenolol, Floating tablets, HPMC, Dissolution, Gastro Retentive.

1. Oral Controlled Release Drug Delivery Systems

Oral controlled release drug delivery is a drug delivery system that provides the continuous oral delivery of drugs at predictable and reproducible kinetics for a predetermined period throughout the course of GI transit and also the system that target the delivery of a drug to a specific region within the GI tract for either local or systemic action [1, 2].

All the pharmaceutical products formulated for systemic delivery via the oral route of administration, irrespective of the mode of delivery (immediate, sustained or controlled release) and the design of dosage form (solid dispersion or liquid), must be developed within the intrinsic characteristics of GI physiology. Therefore the scientific framework required for the successful development of oral drug delivery systems consists of basic understanding of

(i) Physicochemical, pharmacokinetic and pharmacodynamic characteristics of the drug

(ii) the anatomic and physiologic characteristics of the gastrointestinal tract and

(iii) Physicochemical characteristics and the drug delivery mode of the dosage form to be designed.

The main areas of potential challenge in the development of oral controlled drug delivery systems are [3, 4]: -

1) Development of a drug delivery system: To develop a viable oral controlled release drug delivery system capable of delivering a drug at a therapeutically effective rate to a desirable site for duration required for optimal treatment.
2) Modulation of gastrointestinal transit time: To modulate the GI transit time so that the drug delivery system developed can be transported to a target site or to the vicinity of an absorption site and reside there for a prolonged period of time to maximize the delivery of a drug dose.

Minimization of hepatic first pass elimination: If the drug to be delivered is subjected to extensive hepatic first-pass elimination, preventive measures should be devised to either bypass or minimize the extent of hepatic metabolic effect.

1.1 Gastro retentive Dosage Form (GRDF) [5, 6]

It is evident from the recent scientific and patient literature that an increased interest in novel dosage forms that are retained in stomach for a prolonged and predictable period of time exists today in academic and industrial research groups.

One of the most feasible approaches for achieving a prolonged and predictable drug delivery in the GI tract is to control the gastric residence time (GRT), i.e. gastro retentive dosage form (GRDFs or GRDS).

GRDFs extend significantly the period of time over which the drugs may be released. They not only prolong dosing intervals, but also increase patient compliance beyond the level of existing controlled release dosage form.

Dosage form with prolonged GRT, i.e. gastro retentive dosage form (GRDF), will bring about new and important therapeutic options such as –

1) This application is especially effective in sparingly soluble and insoluble drugs, as the solubility of a drug decreases, the time available for drug dissolution becomes less adequate and thus the transit time becomes affecting drug absorption. To override this problem, erodible, gastro retentive dosage forms have been developed that provide continuous, controlled administration of sparingly soluble drugs at the absorption site.
2) GRDFs greatly improve the pharmacotherapy of the stomach through local drug release, leading to high drug concentration at the gastric mucosa. (For e.g. Eradicating Helicobacter pylori from the sub mucosal tissue of Stomach).
3) GRDFs can be used as carriers for drugs with so-called absorption windows. These substances for e.g. antiviral, antifungal and antibiotic agents are taken up only from very specific sites of the GI mucosa.

2. Materials Used

Atenolol, HPMC K 15M, HPMC K 100M, Sodium Carbonate, Micro Crystalline Cellulose, Magnesium Sterate and Talc were procured from SD Fine Chemicals, Mumbai. All other chemicals used were of analytical grade.

3. Methods Used

3.1 Preparation of Atenolol floating tablets

All the formulations were prepared by direct compression method using different viscosity grades of HPMC polymers in various ratios (designated as F-1 to F-8 in Table). The Atenolol and all other ingredients were individually passed through sieve ≠ 60. All the ingredients were mixed thoroughly by triturating up to 15 min. The powder mixture was lubricated with talc. The single punch tablet machine (CADMACH) was used for the compression of the floating tablets. Use of ingredients in the formulation: Sodium bicarbonate was used as the gas generating agent to reduce the floating lag time. HPMC K4M and HPMC K100M were used as the release retardant polymer to obtain prolonged release of the drug up to 8 hours. Microcrystalline cellulose (MCC) was used as the diluent. Magnesium stearate and talc were used as the lubricants. The tablets were prepared by using the direct compression method.

Table 1: Composition of different formulations

Formulation No.	Atenolol (mg)	HPMC K15M (mg)	HPMC K100M (mg)	$NaHCO_3$ (mg)	Mag. Stearate (mg)	Talc (mg)	Microcrystalline cellulose (mg)
F1	50	50	-----	45	3	3	154
F2	50	100	-----	45	3	3	99
F3	50	150	-----	45	3	3	49
F4	50	200	-----	45	2.5	2.5	-----
F5	50	-----	50	45	3	3	154
F6	50	-----	100	45	3	3	99
F7	50	-----	150	45	3	3	49
F8	50	-----	200	45	2.5	2.5	-----

4. Evaluation of Tablets [7, 8, 9, 10]

The formulated tablets were evaluated for the following physicochemical characteristics:

4.1 General appearance

The formulated tablets were assessed for its general appearance and observations were made for shape, color, texture and odor.

4.2 Hardness

Hardness of the tablet was determined by using the Monsanto hardness tester. The lower plunger was placed in contact with the tablet and a zero reading was taken. The plunger was then forced against a spring by turning a threaded bolt until the tablet fractured. As the spring was compressed a pointer rides along a gauge in the barrel to indicate the force.

4.3 Weight Variation

20 tablets were selected and weighed collectively and individually. From the collective weight, average weight was calculated. Each tablet weight was then compared with average weight to ascertain whether it was within the permissible limits or not. Not more than two of the individual weights deviated from the average weight by more than 7.5% for 300 mg tablets and none by more than double that percentage.

4.4 Friability test

20 previously weighed tablets were placed in the friability apparatus, which was given 100 revolutions and the tablets were reweighed. The percentage friability was calculated by using the following formula,

Percentage friability = initial weight-final weight /initial weight × 100.

4.5 Drug content

20 tablets of each formulation were weighed and powdered. The quantity of powder equivalent to 100 mg of Atenolol was transferred in to a 100 ml volumetric flask and the volume adjusted to 100 ml with 0.1N HCl. Further 1ml of the above solution was diluted to 100 ml with 0.1N HCl and the absorbance of the resulting solution was observed at 221 nm.

4.6 *In vitro* Buoyancy studies

The *in vitro* buoyancy was determined by floating lag time, and total floating time. (As per the method described by Rosa *et al*. [8]) The tablets were placed in a 100 ml beaker containing 0.1N HCl. The time required for the tablet to rise to the surface and float was determined as floating lag time (FLT) and the duration of the time the tablet constantly floats on the dissolution medium was noted as the Total Floating Time respectively (TFT).

4.7 Swelling index studies

The swelling behavior of a dosage unit was measured by studying its weight gain. The swelling index of tablets was determined by placing the tablets in the basket of dissolution apparatus using dissolution medium as 0.1N HCl at 37±0.5 °C. After 0.5, 1, 2, 3, 4, 5, and 6h, each dissolution basket containing tablet was withdrawn, blotted with tissue paper to remove the excess water and weighed on the analytical balance (Schimdzu, AX 120). The experiment was performed in triplicate for each time point. Swelling index was calculated by using the following formulae

$$\text{Swelling index} = \frac{\text{(Wet weight of tablet – Dry weight of tablet)}}{\text{Dry weight of tablet.}}$$

4.8 Dissolution Study [11]

900 ml 0f 0.1 HCl was placed in the vessel and the USP apparatus –II (Paddle Method) was assembled. The medium was allowed to equilibrate to temp of 37±0.5 °C. Tablet was placed in the vessel and the vessel was covered, the apparatus was operated for 8 hours at 50 rpm. At definite time intervals, 5 ml of the fluid was withdrawn; filtered and again 5 ml of the fluid was replaced. Suitable dilutions were done with the dissolution fluid and the samples were analyzed spectrophotometrically at 221 nm.

4.9 Release Kinetics [12]

The analysis of drug release mechanism from a pharmaceutical dosage form is an important but complicated process and is practically evident in the case of matrix systems. As a model-dependent approach, the dissolution data was fitted to four popular release models such as zero-order, first-order, diffusion and Peppa's- Korsemeyer equations, which have been described in the literature. The order of drug release from matrix systems was described by using zero order kinetics or first orders kinetics. The mechanism of drug release from the matrix systems was studied by using Higuchi equation and Peppa's- Korsemeyer equation. The results are given in Table.

4.10 Higuchi equation

It defines a linear dependence of the active fraction released per unit of surface (Q) on the square root of time.

$$Q=K_2t^{½}$$

Where, K2 is the release rate constant.

4.11 Power Law

In order to define a model, which would represent a better fit for the formulation, dissolution data was further analyzed by Peppa's and Korsemeyer equation (Power Law).

$$M_t/M_\alpha = K.t^n$$

4.12 Ft-Ir Studies

The FTIR spectra of the drug (alone), polymer (alone) and the drug-polymer (mixture) were recorded by the potassium bromide pellet method. From the infrared spectra it is clearly evident that there were no drug-polymer interactions of the drug.

Data for IR Spectra of Atenolol

Functional Group	Frequency (cm^{-1})
C-H Aromatic (stretching)	3017.49
c=c Aromatic (stretching)	1404.72
C-N (stretching)	1179.15
C-H (stretching)	2870.16
CH_2 (bending)	1421.05
O-H (stretching)	3342.05

5. Results

Table 2: Quality Control Parameters of Atenolol floating Tablets

Formulation No.	Avg. Weight (Mean± S.D)(n=20)	Hardness (kg/cm^2) (n=3)	Friability (Mean±S.D) (n=20)	% Drug content (mg)	Buoyancy Lag time (min)	Total floating Time(hrs)	Matrix integrity
F1	283±0.6	7.2±0.2	0.546	97±0.7	4	8	+
F2	320±0.9	7.5±0.2	0.612	99±0.5	10	8	+
F3	297±0.3	8.0	0.827	100±0.6	8	8	+
F4	291±0.4	7.6±0.2	0.611	99±0.6	6.1	8	+
F5	286±0.8	7.6±0.2	0.625	99±0.6	5.0	8	+
F6	304±0.8	7.3±0.4	0.655	98±0.5	3	8	+
F7	294±0.4	8	0.711	100±0.3	8.5	8	+
F8	292±0.4	7.7±0.5	0.702	99±0.4	8.6	8	+

Table 3: Swelling index studies of Atenolol floating tablets prepared with HPMC K15 M in different ratios.

Time(hr)	Swelling index ratio (n=3)			
	F1	F2	F3	F4
0	0	0	0	0
1	44.64	48.43	51.23	60
2	80.35	101.56	115.6	120
3	98.21	143.75	158.36	169.09
4	103.57	158.62	175.63	223.63
5	110.7	169.5	195	234.54
6	110.7	175.56	200.85	249.09

Table 4: Swelling index studies of Atenolol floating tablets prepared with HPMC K100 M in different ratios.

Time(hr)	Swelling index ratio (n=3)			
	F5	F6	F7	F8
0	0	0	0	0
1	81.03	85.48	92.87	107.14
2	96.55	124.19	132.53	157.14
3	108.62	164.5	180.69	207.14
4	110.34	179.03	190.56	228.57
5	143.1	248.38	269.87	307.14
6	162.06	275.8	290.96	325

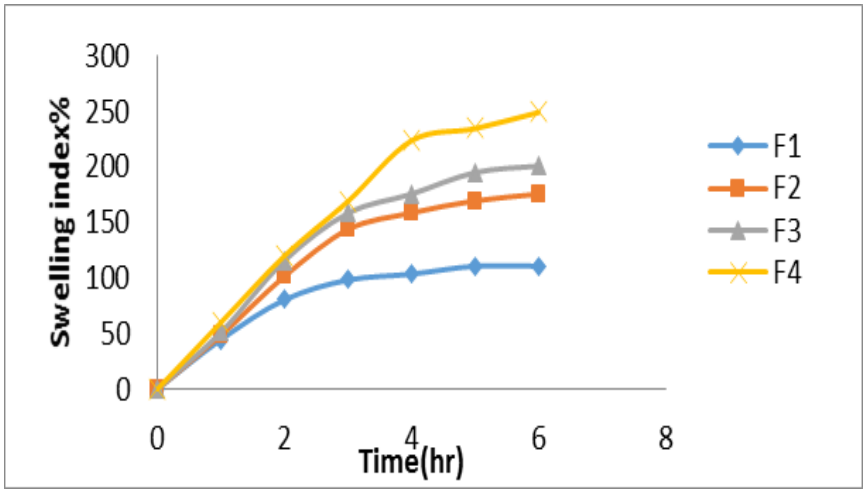

Fig 1: Swelling index of the different formulations (F1-F4)

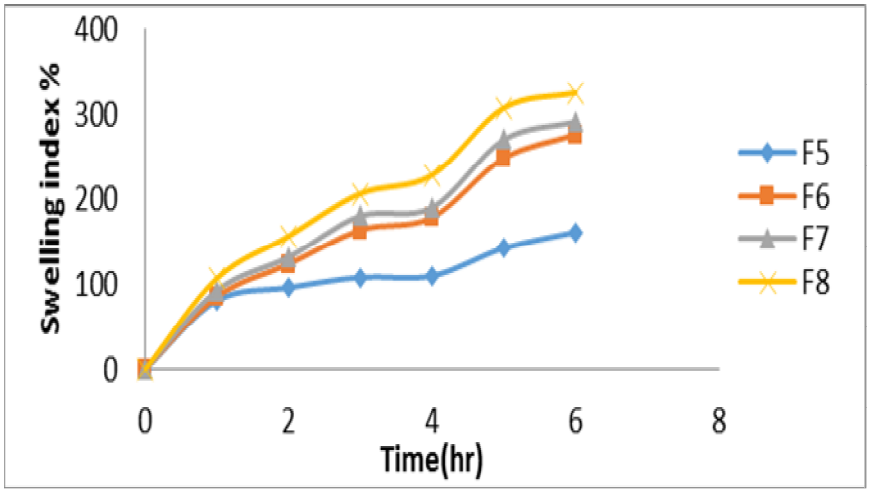

Fig 2*:* Swelling index of the different formulations (F5-F8)

Table 5: Highest swelling index profile of Atenolol floating tablets different formulations

S.NO	Formulation code	Highest swelling index ratio
1	F1	44.64
2	F2	48.43
3	F3	51.23
4	F4	60
5	F5	81.03
6	F6	85.48
7	F7	92.87
8	F8	107.14

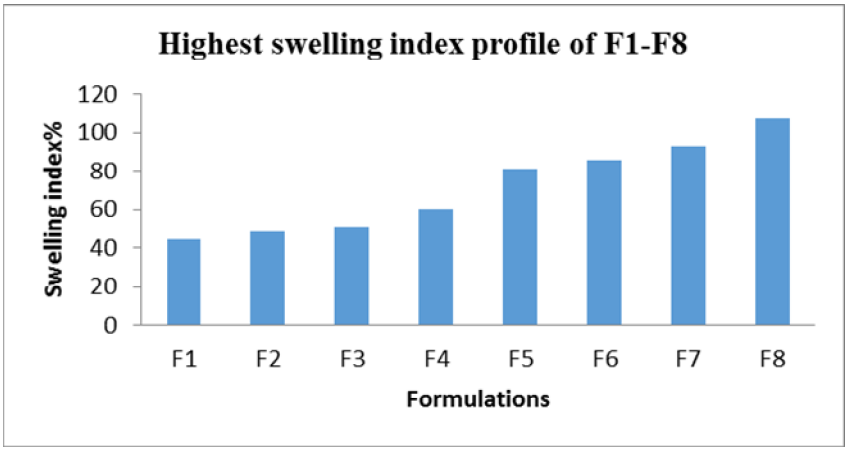

Fig 3: Highest swelling index of the floating tablets

Table 6: Dissolution Data of Atenolol Tablets Prepared with hpmc K15M IN Different concentrations

TIME (hr)	CUMULATIVE percent drug dissolved (n=3±sd)	
	f1	f2
0.5	18.45±0.77	17.76±0.77
1	27.05±0.55	25.02±0.5
2	34±0.69	31.68±0.84
3	42.58±0.99	40.35±0.96
4	49.86±0.77	47.3±0.55
5	55.4±0.95	53.69±0.52
6	65.17±1.25	63.25±0.95
7	70.01±0.95	69.64±1.25
8	76.8±1.08	75.41±0.99

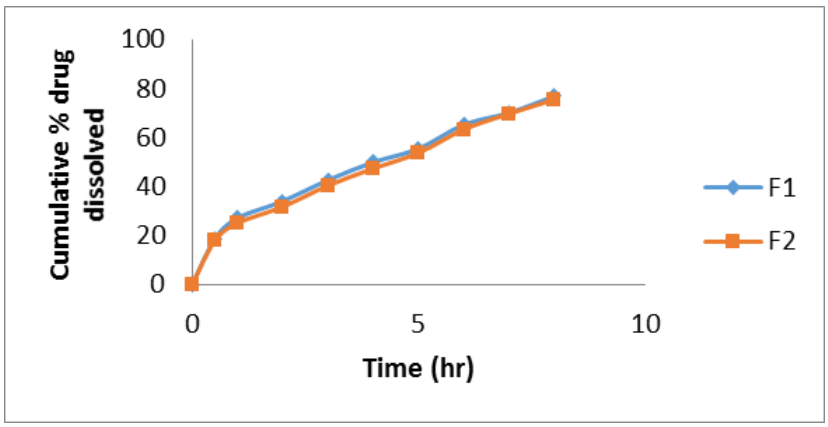

Fig 4: Dissolution profile of Atenolol floating tablets (F1, F2) formulations.

Table 7: Dissolution Data of Atenolol Tablets Prepared with hpmc k 15M IN Different concentrations

TIME (hr)	Cumulative percent drug dissolved (n=3±sd)	
	f3	f4
0.5	16.85±0.65	14.97±0.98
1	20.05±0.25	19.65±1.20
2	31.97±0.62	29.14±1.58
3	40.15±0.85	37.12±0.25
4	46.69±0.78	41.63±0.52
5	50.79±0.85	49.42±0.88
6	61.27±0.95	59.23±0.80
7	66.73±0.58	64±0.95
8	71.34±1.05	70±1.0

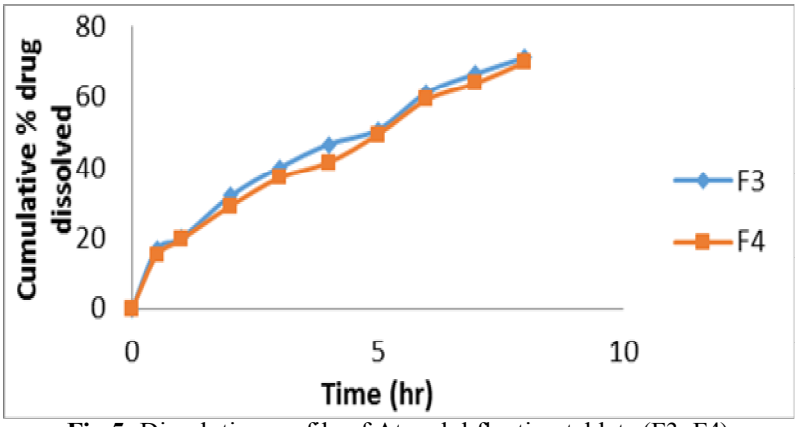

Fig 5: Dissolution profile of Atenolol floating tablets (F3, F4)

Table 8: Dissolution Data of ATENOLOL TABLETS Prepared with hpmc K100M IN Different concentrations

TIME (hr)	Cumulative percent drug dissolved (n=3±sd)	
	f5	f6
0.5	17.46±0.77	15.85±0.55
1	24.9±0.52	20.08±0.66
2	33.41±0.84	29.71 ±0.95
3	40.62±0.66	38.49 ±0.58
4	45.63±0.61	43.32 ±0.39
5	51.26±0.59	49.85 ±0.89
6	60.92±0.35	59.13±0.94
7	66.08±0.92	64.45±0.88
8	70.44±0.94	69.64±0.90

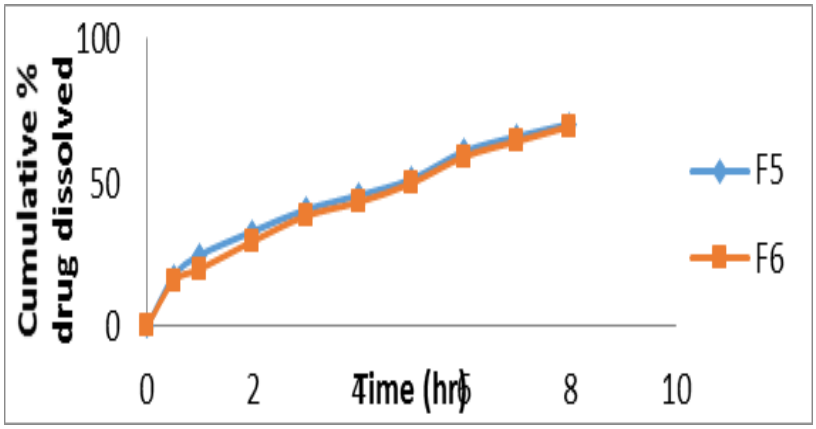

Fig 6: Dissolution profile of Atenolol floating tablets (F5, F6)

Table 9: Dissolution Data of Atenolol Tablets Prepared with HPMC K100M IN Different concentrations

Time (hr)	Cumulative percent drug dissolved (n=3±sd)		
	f7	f8	BRAND
0.5	12.81±0.88	**10.04±0.58**	**9.29±0.52**
1	17.4±0.54	**16.85±0.77**	**15.02±0.74**
2	25.25±0.65	**23.42±0.69**	**21.17±0.45**
3	35.89±0.98	**32.63±0.25**	**29.3±0.52**
4	41.51±0.58	**35.92±0.89**	**32±0.84**
5	47.53±0.85	**41.61±0.58**	**40.83±0.90**
6	49.59±0.69	**47.28±0.98**	**47.23±0.48**
7	59.31±0.58	**52.34±0.58**	**52.74±0.56**
8	62.24±0.85	**61.31±0.65**	**59.67±0.48**

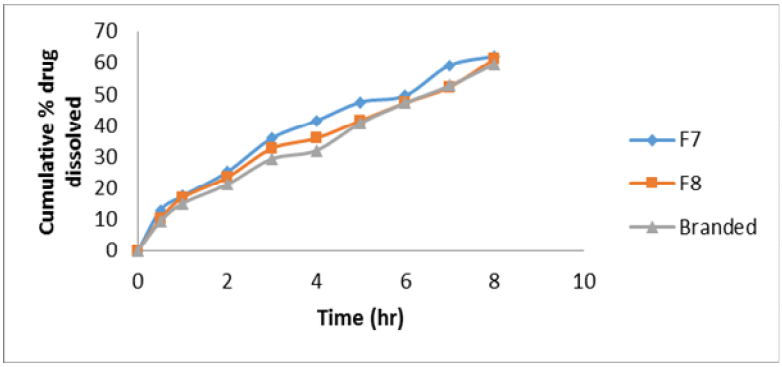

Fig 7: Dissolution profile of Atenolol floating tablets (F7, F8 and Brand) formulations.

Table 10: Release kinetics: Coefficient of correlation (r) values of different batches of Atenolol floating tablets

Formulation	Zero order	First order	Higuchi's	Peppa's
F1	0.976	0.870	0.929	0.934
F2	0.975	0.915	0.954	0.971
F3	0.937	0.940	0.996	0.994
F4	0.971	0.990	0.994	0.995
F5	0.983	0.923	0.957	0.966
F6	0.992	0.954	0.966	0.975
F7	0.975	0.955	0.970	0.985
F8	**0.979**	**0.981**	**0.986**	**0.994**
BRAND	**0.995**	**0.987**	**0.977**	**0.992**

Table 11: Dissolution Parameters of Atenolol Tablets

Formulation	Dissolution Parameters					
	n	$K_{0(\mu g/hr)}$	$K_{1(hr-1)}$	$T_{25(hr)}$	$T_{50(hr)}$	$T_{75(hr)}$
F1	0.492	7.831	0.301	0.9	5	8
F2	0.591	8.084	0.248	1	5.1	8
F3	0.608	8.077	0.223	1.4	5	---
F4	0.612	5.503	0.204	1.5	5.6	---
F5	0.496	7.819	0.186	1	5	----
F6	0.599	7.867	0.175	1.5	5	---
F7	0.621	6.626	0.151	2	6	---
F8	**0.623**	**5.490**	**0.175**	**2.2**	**7**	**---**
BRAND	**0.655**	**6.762**	**0.179**	**2.5**	**7**	**---**

6. Discussion

The objective of the present study was to prepare Floating tablets of Atenolol. These were developed to prolong the gastric residence time and to increase the drug bioavailability. Atenolol was chosen as a model drug because it is better absorbed in the stomach than the lower gastro intestinal tract. The tablets were prepared by direct compression technique, using polymers such as HPMCK15M, HPMC K100M and

other standard excipients. Tablets were evaluated for physical characteristics such as hardness, floating capacity and weight variation. The *in vitro* release characteristics were evaluated for 8 hrs.

Totally 8 different formulations of Atenolol were prepared by using two different polymers like HPMC K15M, HPMC K100M and diluent microcrystalline cellulose in different concentrations. The amount of drug released from all the formulations depends upon the concentration of the polymer used. Finally, the retardant effect of the polymer on the drug release can be indicated as

HPMC K100M > HPMC K15M.

Swelling is crucial in determining the release rate. A direct correlation between swelling and drug release was observed and the swelling indices were increased with increase in polymer concentration. Among all the formulations the F8 formulation containing HPMC K100M shows the best result of swelling index.

Among all the formulations the F8 formulation containing HPMC K100M shows the best result. The result was compared with the branded formulation. The result was satisfactory.

Tables enlist the various dissolution parameters computed for all the controlled release floating tablets. To examine the release mechanism of Atenolol floating tablets, the results were analyzed according to Korsmeyer- Peppas equation.

Release of Atenolol from the optimized formulation (F8) was found to follow First order kinetics (correlation coefficient, r^2 value 0.981).

Higuchi plot showed an r^2 valve of 0.986 for formulation F8 suggesting that the diffusion plays an important role in the controlled release. The data was fitted to Korsmeyer equation; and the value of diffusion exponent 'n' (0.623) indicated that the drug release shows Non-fickian diffusion.

7. Conclusion

The Atenolol is a selective β1-adrenoreceptor blocking agent which is used in the treatment of hypertension. In this study Atenolol tablets were prepared by using different polymers like HPMC K15M and K100M.

Eight formulations of floating tablets of Atenolol were developed by direct compression technique. The F8 formulation was found to be best of all the trials showing that the drug release matches with the brand product.

The best formulation F8 can successfully be employed as a controlled release floating drug delivery system. The floating tablets can control the fluctuations in the plasma drug concentration, increase the gastric residence time and eventually improve the bioavailability of the drug. Based upon the FTIR studies we conclude that there is no drug-excipient interactions.

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