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Original article

Comparative *in vitro* Quality Evaluation of Brands of Propranolol Hydrochloride Tablets Available in the Libyan Market

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Abstract
Propranolol, a beta-blocker, is used in the management of cardiovascular conditions such as irregular heart rate and high blood pressure. The study was carried out to examine the in vitro quality control tests for four brands of propranolol hydrochloride 10 mg tablets, sold in community pharmacies in Tripoli, Libya. The parameters determined were identification, weight variation, friability, hardness, disintegration, dissolution rate, and assay of the tablets. The tablets were evaluated for conformity with USP and BP specifications. Results obtained showed that tablet weight in the range of 51.2 ±1.03mg to 150.1±1.60mg, friability of < 1 % for all brands, hardness ranged from 3.406±3.41 to 6.122±0.47 kg/cm^{2,} disintegration time of 0.8 ± 0.37 to 7.62 ± 0.47minutes, whereby one brand is uncoated tablets and assay of 90.41±0.038 to 109.90 ±0.011% with two brands deviating from the specified limit. The four brands also released more than 80% of their drug content within 30 minutes. Analysis of similarity factor f2 and difference factor f1, revealed that none of the brands can be interchangeable with brand A in terms of dissolution profile in 0.1 M HCl and in phosphate buffer (pH 6.8). The study showed that propranolol samples examined passed all the Pharmacopoeial tests for satisfactory quality except specifications of drug content, where brand A and brand C did not comply with the Pharmacopoeial limits. Thus, not all brands can be used interchangeably in clinical practice.
Keywords. Propranolol, Quality Control, Dissolution, Pharmacopoeial Specification.

Introduction

Propranolol hydrochloride is a non-selective beta-adrenergic antagonist used to treat hypertension, angina pectoris due to coronary atherosclerosis, atrial fibrillation, myocardial infarction, migraine, essential tremor, hypertrophic subaortic stenosis, pheochromocytoma, proliferating infantile hemangioma, and anxiety [1].

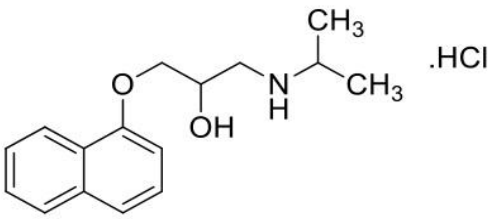

Figure 1. Structure of Propranolol hydrochloride [2].

Propranolol is chemically known as (2RS)-1-[(1-Methylethyl) amino]-3-(naphthalene-1-yloxy) propane-2-ol hydrochloride. It has a molar mass of 259.34 g/mol and a melting point of 96 ˚C [3]. Propranolol tablets come in strengths of 10mg, 40mg, 80mg, or 160mg. The slow-release capsules are 80mg or 160mg. The liquid comes in strengths of 5 mg, 10mg, 40mg, or 50mg in 5ml. Propranolol has a long duration of action as it is given once or twice daily depending on the indication [1,4]. Propranolol is well absorbed orally, but it undergoes extensive first-pass metabolism in the liver, which significantly reduces its bioavailability to approximately 25-35%. Food may enhance the bioavailability by reducing first-pass metabolism. Hepatic impairment can increase plasma concentration due to reduced clearance [5]. It is widely distributed throughout the body, including the central nervous system (CNS). It is highly lipophilic and about 90-95% is bound to plasma proteins [6]. Propranolol is extensively metabolized by the liver via cytochrome P450 enzymes, mainly CYP2D6. Major metabolites include 4-hydroxypropranolol and naphthyloxyacetic acid [5]. The elimination half-life is about 3 to 6 hours, though this can vary depending on the formulation (immediate vs. extended-release). Metabolites are excreted primarily in the urine [6].
The importance of the quality, efficacy, and safety of pharmaceutical products to safeguard public health cannot be overemphasized. The world at large and more especially the third world countries are facing the danger of substandard, fake, or adulterated drugs, treatment failure, and drug toxicity, as well as other adverse health implications arising from the circulation of unwholesome drug products. The World Health Organization (WHO) has posited that about 10 % of the world's pharmaceutical trade in developing countries consists of fake or substandard products, while up to 25% of all drugs consumed in poor resource economies are alleged to be counterfeit or substandard [7-9].

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With the increase in demand for pharmaceutical products comes the production of different categories of these products and diversity in brands. It has therefore become a necessity to keep the quality of pharmaceutical products in constant check, especially those that have already found their way to the market, ready for patients' consumption. Comparative analysis of the different available brands against the official standard would be an effective measure to ascertain the quality of these products, ensuring that they meet required specifications, and to detect sub-standard products. The primary aim of this study is to evaluate and compare the quality of different commercially available brands of propranolol hydrochloride tablets marketed in Tripoli, Libya, to ensure their compliance with pharmacopeial standards and assess their interchangeability and therapeutic efficacy.

Methods

The study was conducted from April to May 2025 at the Department of Pharmaceutics, Faculty of Pharmacy, University of Tripoli. The study involved the evaluation of several quality control parameters, including weight variation, friability, hardness, thickness and diameter, disintegration, and drug content. Additionally, the dissolution and FTIR analyses were carried out at the Medicine and Food Control Center.

Fourier-Transform Infrared Spectroscopy (FTIR)

FTIR spectra were obtained by using an FTIR spectrometer. The samples were mixed thoroughly with potassium bromide (KBr) in a sample-to-KBr ratio of about 1:5, respectively. The KBr discs were prepared by compressing the powders at a pressure of 5 tons for 5 min in a hydraulic press. Scans were obtained at a resolution of 4 cm^{-1} from 4000 to 300 cm^{-1}.

Weight variation test

In this test, 20 tablets of propranolol HCl (10mg) were selected randomly from different companies. These tablets were weighed individually. Weight variation was determined using the following equation:

(individual weight − average weight)/ average weight × 100 .....Eq1

The sample meets the standards if the individuals don't differ from the mean by more than is accepted in terms of percentage. That means if no more than two tablets exceed the percentage limits and if no tablet varies by more than two times the accepted limit in terms of percentage, the tablets will meet the USP weight variation test.

Table 1: USP Weight Variation test [10].

Average weight of tablet (mg)	Maximum (%) weight difference allowed
130 or less	10
130-324	7.5
More than 324	5

Friability test

A friabilator was used to evaluate the friability and to assess the tendency of the tablet to chip, crumble, or break upon handling or compression, as well as the strength of the tablet. A pre-weighed 10 tablets sample is placed in the friabilator (Pharma friabilator tester). The friabilator was operated at 100 rpm. The weight of the tablet was assessed before and after a specified number of revolutions, so the weight loss can be evaluated. Tablets can pass the friability test if the percentage of weight loss is within the range of 0.5%-1% of tablet weight. The percent friability can be determined using the following equation [11].

% Friability = I-F\I × 100 .....Eq2

Where **I** represent the initial weight and **F** denotes the weight after friability.

Hardness test

The force required to diametrically break a tablet can be defined as hardness, which represents the crushing strength of a tablet. The crushing strength of a tablet can be evaluated using n (rweka hardness tester. From each brand, a ten-tablet sample was tested, and the pressure required to break the tablet was recorded as Kg/cm^2 [12].

Limit: Typically between 4–10 kgf depending on tablet type (uncoated: 4–8 kgf, coated: 6–10 kgf).

Determination of tablet dimensions (thickness and diameter)

10 tablets from each brand were taken, and both the thickness and diameter of the tablet were determined using an Erweka hardness tester. The mean and standard deviation were calculated for each brand [12].

Limit of thickness: Should not vary by more than ±5% from the average tablet thickness.

Limit of diameter: Should not vary by more than ±5% from the average diameter (no official pharmacopeial limit.

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Disintegration test

The disintegration time of the tablet was assessed by using a USP disintegration apparatus (Pharma tester); the apparatus is composed of 6 tubes open at both ends, where the bottom of the tube is composed of a 10-mesh screen. The medium was simulated body fluid, and the temperature was kept at 37±2 °C. The disintegration time was determined when the complete disintegration of the tablet occurred. Limit of Uncoated Tablets: Must disintegrate within 15 minutes. Limit of Film-Coated Tablet: Must disintegrate within 30 minutes.

Dissolution test

The quality of marketed propranolol tablets was assessed using dissolution experiments carried out on marketed tablets fabricated by different companies. USP Apparatus 1 (basket) (Erweka tester) was used to study the in vitro drug release. The temperature was adjusted to 37.0±0.5 °C, and the rotation of the paddle was 100 rpm. Branded tablets of different companies were placed in 900 ml (0.1N HCl). An aliquot of 5 ml of release medium was withdrawn at predetermined time intervals (5, 10, 15, 30, 45, 60 min) and substituted with an equal volume of fresh medium to maintain a constant volume. These aliquots of release medium were filtered through a 0.45m cellulose acetate membrane filter unit before analysis. Analysis of samples was then performed using a Cary 50 UV-Visible spectrophotometer at 290nm. The same test was done using phosphate buffer (pH 6.8).
Limit: Not less than 80% of the labeled amount dissolved in 30 minutes.

Analysis of dissolution data

A- Model-Independent Method

Similarity factor (f2)

Similarity factor (*f*2) has been adopted by the United States Food and Drug Administration (FDA) and the European Agency for the Evaluation of Medicinal Products to compare dissolution profiles [13,16]. The dissolution profiles were analyzed by a mathematical model, the similarity factor (*f*2). Mean dissolution values were employed to estimate the similarity factor (*f*2). A factor value of 50 or greater (50-100) ensures the sameness or equivalence of the two products.

$$f_2 = 50 \times \log_{10}\left[\frac{100}{\sqrt{1 + \frac{\sum_{t=1}^{n}(R_t - T_t)^2}{n}}}\right]$$

.....Eq3

Where n is the number of time points, R is the dissolution value of the reference product at a time 't, and T is the dissolution value for the test product at a time.

Difference Factor (f1)

The difference factor (*f*1) is a model-independent method used to compare the dissolution profiles of two drug products—usually a test product and a reference product [15,16].

$$f_1 = \frac{\sum_{t=1}^{n}|R_t - T_t|}{\sum_{t=1}^{n}R_t} \times 100$$

.....Eq4

Where R_t and T_t are the percentages dissolved at each time point t for the reference and test products, respectively.
An *f*1 value between 0 and 15 suggests that the two dissolution profiles are similar [17].

B-Model-dependent Method

To evaluate the kinetics of drug release from the tablets, the results of the vitro drug release study of formulations were fitted with various kinetic equations like zero-order, first-order, Higuchi, and Korsmeyer–Peppas model.
The equations of different release kinetics are given below:

-Zero-order kinetics: $Q_t = Q_0 + K_0t$ Eq5
-First-order kinetics: $\log Q_t = \log Q_0 + K_1t/2.303$ Eq6
-Higuchi kinetics: $Qt = K_ht^{1/2}$ Eq7
-Korsmeyer–Peppas kinetics: $Q_t/Q_0 = {}_Kt^n$ Eq8

Where, K_0, $K_1$and K_h indicate Zero-order, First-order, and Higuchi rate constants respectively,

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Q_t/Q_0 means the fraction of drug released at time t, K means the rate constant, and n means the release exponent. The kinetics that gives a high regression coefficient (R^2) value are considered the best fit model.

Drug content

The chemical assay test for each brand of propranolol was carried out as stated in the BP. The quantity of powdered tablets containing 20 mg propranolol hydrochloride was shaken with 20 mL of water for 10 minutes. Fifty mL of methanol was added, and the mixture was shaken for another 10 minutes. Sufficient methanol was then added to make 100 mL, and it was filtered. Samples were suitably diluted and analyzed by UV spectrophotometry at a wavelength of 290 nm. Determination of propranolol hydrochloride was carried out in triplicate for each brand of tablet, taking 206 as the value of A(1%, 1 cm) at the maximum at 290 nm [18].

Limit: 95% to 105% of the labeled amount.

Results and discussion

FTIR spectra of propanol hydrochloride showed a characteristic peak of OH stretch at 3435.84 cm-1. -NH stretch at 3330.11 cm-1, -CH stretch at 2928.33. A peak of acryl C=C symmetric aromatic ring stretching at 1632.65 cm-1 and aryl coupling C-O-Stretching at 1268.17 cm-1, which peak was obtained from 1500cm-1. An aryl O-CH2 asymmetric stretching at 1240.96 and symmetric stretching at 1074.95 cm-1. A peak at 771 cm-1 due to α-substituted naphthalene [19,20].

All four brands (A, B, C, and D) show peaks that fall within the expected ranges for an Alcohol, an Ether, a Secondary Amine and a monosubstituted naphthyl Ring. This suggests that all four samples are chemically very similar and likely contain the same core structure with these functional groups (propranolol).

Table 2. Description of different brands of Propranolol HCl 10 mg tablets

Brand Code	A	B	C	D
Shape	Circular	Circular	Circular	Circular
Color	Pink	Pink	White	White
Scoring	Not scored	Scored	Not scored	Scored
Coating	Film coated	Film coated	Un coated	Film coated
Batch No.	230190	PA757	356133	PJM2300310A
Manufacturing date	05/2023	Not present*	4/2023	Not present*
Expiry date	04/2026	05/2026	4/2028	2/2026
Company	AstraZeneca	Accord	Hikma	Milpharm
Country of origin	Egypt	UK	Jordan	UK

**Brands A and B lack a manufacturing date because the expiration date is the legally required and most critical piece of information for consumers regarding a drug's safety and efficacy*

Fourier-Transform Infrared Spectroscopy (FTIR)

Table 3. Frequency readings from different spectra and ranges for different functional groups.

Functional Group	IR Frequency Ranges	Assignments (Intensity)	Frequencies from sample spectrum (cm^{-1})			
			A	**B**	**C**	**D**
Alcohol (O-H)	3200-3600	O-H stretching (strong)	3383.14	3383.14	3483.44	3383.14
Ether (C-O-C)	1050-1250	C-O-C stretching (strong)	1114.86	1111.00	1118.71	1165.00
2° Amine (C-NH-C)	1580-1650	N-H bending (medium)	1639.49	1654.92	1651.07	1654.92
Naphthyl ring (mono-substituted)	730-770	C-H out-of-plane bending (strong)	770	770	770	770
Matching score compared with brand A			100%	98.6%	93.2%	95.4 %

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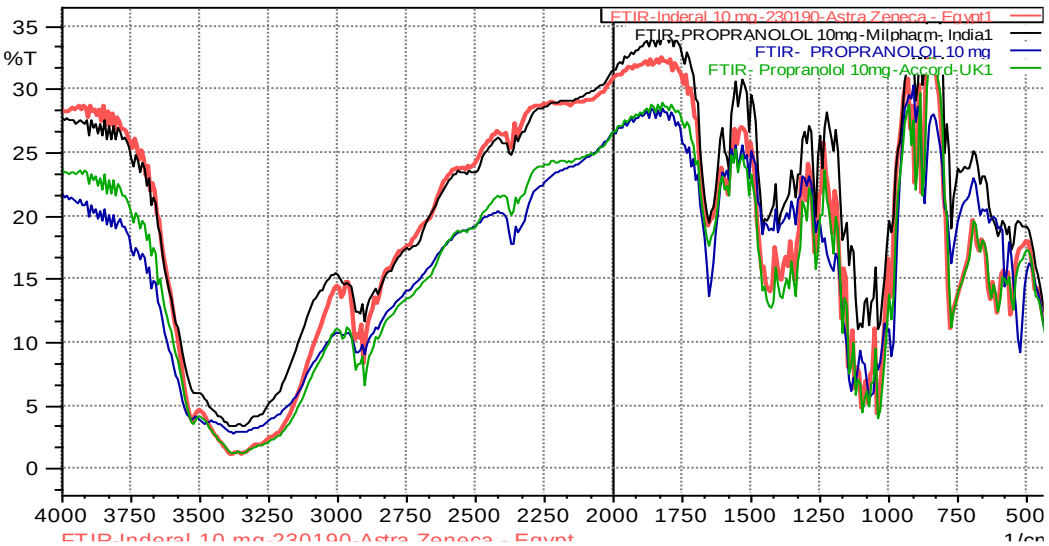

Figure 2. FTIR Spectra of four brands of Propranolol HCl 10 mg tablet.

The matching score in FTIR analysis, quantifies how closely an unknown spectrum matches a reference spectrum. High scores (>90%): Suggest a strong match, confirming the identity of the unknown substance when compared to the reference. Brand B is the closest match at 98.6%, brand D is next at 95.4%, while brand C shows the largest difference at 93.2%, which correlates with its significant frequency shift.

Table 4. Thickness and Diameter of Propranolol Tablet Brands

Brand Code	Mean thickness (mm) ± SD	Mean thickness variation in % ± SD	Mean diameter (mm) ± SD	Mean diameter variation in % ± SD
A	2.685 ± 0.02	0.566 ± 0.34	6.613 ± 0.00	0.063 ± 0.03
B	6.097 ± 0.01	0.157 ± 0.16	6.095 ± 0.01	0.164 ± 0.14
C	2.721 ± 0.02	0.705 ± 0.52	7.13 ± 0.02	0.196 ± 0.25
D	5.157 ± 0.00	0.081 ± 0.04	5.163 ± 0.02	0.25 ± 0.31

All measured tablets exhibited thickness and diameter variation well within the commonly accepted ±5% limit.

Table 5. Weight Variation, Friability, Hardness, and Disintegration Time of Four Brands of Propranolol Tablets.

Brand Code	**Average Weight (g) n=20**	**%Weight Variation n=20**	**% Deviation of the individual Tablet Weight**	**Friability (%) n=10**	**Hardness (kg/cm²) n=10**	**Disintegration Time (min) n=6**
	Mean ± SD	**Mean**	**Min. and Max.**	**Mean**	**Mean ± SD**	**Mean ± SD**
A	99.9 ± 1.33	1.121	0.100 and 1.101	0.0320	5.347 ± 0.28	0:04:15 ± 0:00:55
B	96.7 ± 1.22	1.055	0.310 and -1.758	0	6.122 ± 0.47	0:07:37 ± 0:00:28
C	150.1 ± 1.62	0.759	0.066 and -2.065	0.335	4.128 ± 0.43	0:00:48 ± 0:00:22
D	51.2 ± 1.01	1.64	0.390 and 3.515	0	3.406 ± 0.22	0:01:33 ± 0:00:27

For brands A, B, D All tablet weights are within ±10% of the average weight, while for brand C, all tablets weights are within ±7.5% of the average weight.Therefore, the tablets pass the USP weight variation test. The percentage weight loss (friability) was less than the USP limit of 1% for all tested brands, so all tested brands passed the friability test. Regarding the hardness test,Brands A.B and C are within the acceptable limit according to USP, crushing force of 4-8 Kg,while brand D shows hardness below the pharmacopeial limit(3.406 ± 0.22). The BP specification is that uncoated tablets should disintegrate within 15 minutes and film -coated tablets within 30 minutes while USP specifies that uncoated and film- coated tablets should disintegrate within 30 min. n four brands, all six tablets disintegrated within 30 minutes. Therefore, the results are acceptable according to USP general disintegration test criteria for a film- coated tablet. The type and amount of disintegrant used heavily influence the disintigration time.Also Higher

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compression force results in a denser, less porous tablet with stronger interparticle bonds, which typically slows down fluid penetration and increases disintegration time.

Table 6. Dissolution Data of Four Brands of Propranolol Tablets in 0.1 N HCl.

Time (minutes)	% Released (Mean ± SD)			
	A	B	C	D
0	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
5	12.67±0.51	28.71 ±1.07	50.96 ±0.1	81.20 ±0.21
10	79.96±0.28	35.77 ±0.19	67.53 ±0.08	93.55 ±0.97
15	96.21±0.06	58.57 ±0.22	73.90 ±0.09	94.77 ±0.03
30	101.5 ±0.13	88.73 ±0.07	84.38 ±0.55	92.92 ±0.18
45	101.42 ±0.12	82.92 ±0.34	79.03 ±0.22	93.82 ±0.8
60	102.18 ±0.03	84.24 ±0.61	76.07 ±0.11	92.28 ±0.03

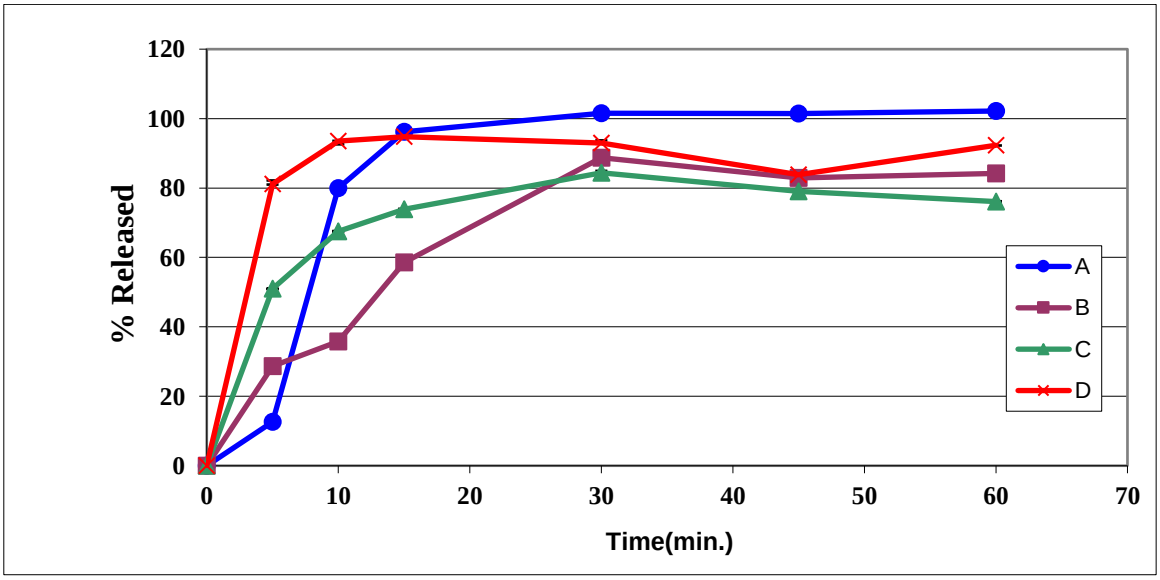

Figure 3. Dissolution Profiles of Four Brands of Propranolol HCl Tablets in 0.1 M HCl.

The USP specifies that the amount of drug released should not be less than 80% of the labeled amount at 30 minutes [21]. Findings of this study are presented in the Table 6 (dissolution in 0.1 M HCl). Based on these findings, all four brands (A, B, C, and D) complied with the USP and BP requirements. Their drug release at 30 minutes was 101.5% for Brand A, 88.73% for Brand B, 84.38% for Brand C, and 94.77% for Brand D, all exceeding the 80% threshold. Some dissolution values were observed to be slightly above 100%, which is within the acceptable margin of error for the analytical method and may be attributed to minor variability in the tablet assay value. Thus, all the batches passed the dissolution test, and their active pharmaceutical ingredient would be readily bioavailable for absorption when ingested.

Table 7. f1 and f2 Values for Dissolution Profiles of Four Propranolol Brands in in 0.1 HCl.

Brand code	*f1 (Difference Factor)*	*f2 (Similarity Factor)*
A	***Reference Product***	***Reference Product***
B	***29.78***	***28.22***
C	***28.07***	***30.54***
D	***22.20***	***26.72***

In the acidic medium (HCl), the dissolution profiles of Brand B, Brand C, and Brand D showed significant dissimilarity when compared to the reference product. Specifically, the f1 values for all test brands were notably above the acceptable threshold of 15 (Brand B: 29.78, Brand C: 28.07, Brand D: 22.20), indicating considerable differences in their release behavior. Additionally, the corresponding f2 values (Brand B: 28.22, Brand C: 30.54, Brand D: 26.72) were well below the similarity acceptance limit of 50, further confirming a lack of equivalence in the dissolution profiles. These results suggest that none of the tested formulations achieved the required similarity to the reference in acidic conditions.

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Table 8. R^2 values of Four Brands of Propranolol in 0.1 N HCl.

Brand code	Zero-order (R^2)	First-order (R^2)	Higuchi model (R^2)	Krosmeyer-Peppas model
A	0.519	0.757	0.727	0.589
B	0.667	0.660	0.857	0.827
C	0.511	0.708	0.786	0.874
D	0.281	0.409	0.556	0.564

The analysis of drug release kinetics reveals distinct mechanisms for each brand.Brand A follows First-order kinetics, typical of conventional immediate-release tablets where the release rate decreases as the drug depletes. Brand B best fits the Higuchi model, indicating a diffusion-controlled release mechanism from a matrix system. Brand C's release is best described by the Korsmeyer-Peppas model, suggesting a complex mechanism that could involve both diffusion and polymer relaxation; further analysis of the release exponent 'n' would be required for a definitive mechanism. Notably, Brand D shows a poor fit to all models (highest R^2 = 0.564 for Korsmeyer-Peppas), indicating erratic and non-ideal drug release. This lack of a defined release mechanism could translate to inc

Dissolution test in phosphate buffer (pH 6.8)

The BP specifies that the amount of drug released should not be less than 80% of the labeled amount at 30 minutes [22]. The findings of this study, presented in the table 9, show that all four brands (A, B, C, and D) complied with the USP and BP requirements. Their drug release at 30 minutes was 89.42% for Brand A, 86.02% for Brand B, 95.99% for Brand C, and 103.70% for Brand D, all exceeding the 80% threshold. It is noted that some measured values for Brand D slightly exceeded 100%; this is within the accepted variability of the analytical method and does not impact the conclusion of compliance. Thus, all batches passed the dissolution test, and their active pharmaceutical ingredient would be readily bioavailable for absorption when ingested

Table 9. Dissolution Data of Four Brands of Propranolol in phosphate buffer (pH 6.8).

Time (minutes)	% Released (Mean ± SD)			
	A	B	C	D
0	0.00 ±0	0.00 ±0	0.00 ±0	0.00 ±0
5	27.41±1.61	19.46 ±0.48	62.24 ±0.33	32.95±4.18
10	44.59±1.57	45.67±0.74	81.28 ±1.91	35.61±0.24
15	67.06 ±1.46	51.19 ±1.53	86.12 ±0.38	75.05± 0.25
30	89.42 ±0.76	86.02 ±0.28	95.99 ±0.66	103.7 ±1.25
45	91.25 ±2.37	92.29 ±0.57	87.13±0.38	102.77±1.96
60	101.05 ±0.12	100.12 ± 0.4	88.55±0.99	95.25 ±0.14

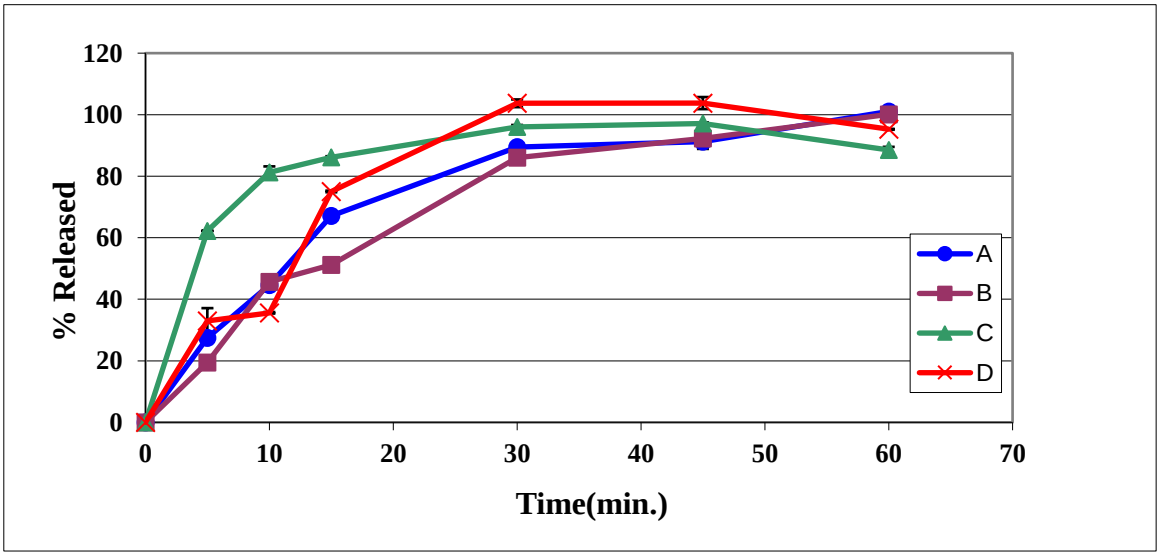

Figure 4. Dissolution Profiles of Four Brands of Propranolol HCl Tablets in phosphate buffer (pH 6.8).

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Table 10. f1 and f2 Values for Dissolution Profiles of Four Brands of Propranolol Tablets in phosphate buffer (pH 6.8).

Brand code	f1 (Difference Factor)	f2 (Similarity Factor)
A	Reference Product	Reference Product
B	22.83	30.6
C	19.11	32.57
D	19.49	32.94

In phosphate buffer medium, the dissolution profiles of Brand B, Brand C, and Brand D also failed to meet the criteria for similarity with the reference product. The f1 values for all tested brands (Brand B: 22.83, Brand C: 19.11, Brand D: 19.49) exceeded the acceptable limit of 15, indicating notable differences in release behavior. Likewise, the f2 values (Brand B: 30.60, Brand C: 32.57, Brand D: 32.94) were below the required threshold of 50, suggesting that the formulations do not exhibit sufficient similarity to the reference product in this medium. Overall, none of the brands demonstrated acceptable dissolution similarity in phosphate buffer conditions.

Table 11. R^2 values of Four Brands of Propranolol Tablets in phosphate buffer (pH 6.8).

Brand code	Zero-order (R^2)	First-order (R^2)	Higuchi model (R^2)	Krosmeyer-Peppas model
A	0.797	0.955	0.950	0.928
B	0.860	0.967	0.966	0.930
C	0.464	0.776	0.746	0.848
D	0.742	0.843	0.899	0.848

The analysis of release kinetics in phosphate buffer reveals a clear distinction in formulation behavior. Brands A and B demonstrate excellent fits ($R^2 > 0.95$) to the First-order model, indicating a conventional and highly consistent immediate-release mechanism. This suggests well-controlled formulations with likely similar, highly soluble excipient compositions. In contrast, Brands C and D show weaker and more variable fits. Brand C's release is best described by the Korsmeyer-Peppas model ($R^2 = 0.848$), suggesting a complex mechanism potentially involving polymer swelling, while Brand D follows a diffusion-controlled Higuchi model ($R^2 = 0.899$). This divergence in the dominant release mechanisms highlights significant variability in the excipients used—such as the type of matrix-forming polymers or fillers—compared to the reference product. This formulation variability is a key factor underlying the lack of dissolution profile similarity previously observed and could impact batch-to-batch consistency and in-vivo performance."

Drug content

The results for the content of active pharmaceutical ingredient (API) in the four brands of propranolol hydrochloride tablets, determined using the UV spectrophotometric method, are presented in Table 12. The British Pharmacopoeia (BP) specification requires the API content to be not less than 95% and not more than 105% of the labeled claim. The assay results demonstrate that only two of the four brands complied with this pharmacopeial standard: Brand B (96.07%) and Brand D (95.27%) were found to be compliant. The following two brands failed the assay test and were non-compliant with BP standards: Brand A (109.90%) was non-compliant, as it significantly exceeded the 105% upper limit, indicating a super-potent product. Brand C (90.41%) was non-compliant, as it fell below the 95% lower limit, indicating a sub-potent product. While a tablet should ideally contain exactly 100% of the labeled drug, variations in the manufacturing process (e.g., non-uniform distribution of the drug in the powder blend, or inconsistent tablet weight) can lead to some tablets having a slightly higher or lower actual drug content. Sometimes a formulation is intentionally manufactured with a slight "overage" to ensure that the product still meets the minimum label claim throughout its shelf life, accounting for potential degradation over time.

Table 12. Drug Content Analysis of Four Brands of Propranolol Tablets

Brand	Absorbance (1)	Absorbance (2)	Absorbance (3)	Average Absorbance	Drug Content (%)
A	0.894	0.906	0.917	0.9056	109.90±0.011
B	0.791	0.833	0.751	0.7916	96.07±0.041
C	0.789	0.720	0.725	0.745	90.41±0.038
D	0.790	0.769	0.797	0.785	95.27±0.015

Shuma ML et al evaluated four propranolol 10 mg tablet brands in Bangladesh and found all showed similar dissolution profiles to the reference ($f2 > 50$, $f1 < 15$), with over 80% drug release in 30 minutes, following mainly first-order and Hixson-Crowell kinetics [23]. In contrast, our study on four brands

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available in Tripoli showed that, although all met the ≥80% release at 30 minutes, none showed similarity to the reference product (f2 < 50, f2 > 15). The kinetic models also varied, suggesting greater variability in formulation quality among the in our study.

Conclusion

All tested brands complied with basic physical quality tests, including weight variation, friability, hardness (except brand D, which showed lower hardness), disintegration, and tablet dimensions—falling within the pharmacopeial acceptance limits. However, differences were observed in chemical and dissolution behavior: FTIR analysis confirmed the presence of key functional groups in all brands, indicating the presence of propranolol HCl. Drug content assay showed that Brand A exceeded the upper pharmacopeial limit (109.9%), while Brand C fell below the minimum acceptable content (90.41%), indicating possible issues with manufacturing consistency. Dissolution tests in both 0.1 N HCl and phosphate buffer pH 6.8 revealed that all brands met the USP requirement of ≥80% release at 30 minutes. However, based on the model-independent method ($f1$ and $f2$), none of the test brands showed significant similarity in dissolution profiles compared to the reference (Brand A) in phosphate buffer and in 0.1N HCl. Kinetic modeling showed that Brands A and B followed first-order release kinetics, indicating concentration-dependent drug release, whereas Brands C and D followed mixed or lower-order release models. Overall, while all brands passed the basic quality control tests, variability in drug content and dissolution similarity raises concerns about their therapeutic equivalence. This highlights the need for continued post-market surveillance, strict adherence to manufacturing standards, and the implementation of robust bioequivalence assessments for generic products to ensure patient safety and drug efficacy in the Libyan pharmaceutical market.

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Disclaimer

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Conflicts of Interest

There are no financial, personal, or professional conflicts of interest to declare.

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