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Questions & Answers: positions on specific questions addressed to the pharmacokinetics working party

Background

In the context of assessment procedures, the Pharmacokinetics Working Party (PKWP), or its predecessor the Therapeutic Subgroup on Pharmacokinetics of the Efficacy Working Party (EWP-PK subgroup), is occasionally consulted by the CHMP or, following CHMP's agreement, by other Committees, Working parties or the CMD(h). The objective is to address specific questions in relation to pharmacokinetic evaluations and particularly the requirements and assessment of bioequivalence studies. The positions, which are being elaborated by the PKWP in response to such questions, are being forwarded to the enquiring party for consideration in their assessment.

It is understood that such position will be reflected in the procedure-related assessment reports if applicable. In some cases however, these position might also be of more general interest as they interpret a very specific aspect that would not necessarily be covered by guidelines. This paper summarises these positions which have been identified as being within this scope. In addition, general clarifications related to guidelines authored by the PKWP are subject to specific positions in this paper.

It should be noted that these positions are based on the current scientific knowledge as well as regulatory precedents. They should be read in conjunction with the applicable guidelines on bioequivalence in their current version. If the questions have initially been raised in the context of specific assessment procedures, details of these procedures have been redacted for reasons of confidentiality.

This compilation will be updated with new positions as soon as they become available. Likewise, if a position is being considered outdated, e.g. due to new evolutions in the scientific knowledge including revisions to the applicable guidelines, positions will be removed from this document. Positions previously prepared by the EWP-PK subgroup are endorsed by the current PKWP unless removed from this document.

The positions in this document are addressing very specific aspects. They should not be quoted as product-specific advice on a particular matter as this may require reflection of specific data available for this product. By no means should these positions be understood as being legally enforceable.

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TABLE OF CONTENTS

1. Cocktail studies for investigating <i>in vivo</i> drug interaction potential.....	3
2. Requirements for food-interaction studies for modified release formulations.....	4
3. Bioequivalence studies in children	8
4. Bioequivalence of gastro-resistant preparations (e.g. omeprazole)	9
5. Bioequivalence studies for generic products containing clopidogrel	11
6. Acceptance criteria for bioequivalence studies for losartan	14
7. Bioequivalence assessment of generics for tacrolimus.....	15
8. Requirements for demonstration of bioequivalence for ciclosporine generics.....	17
9. Requirements for demonstration of bioequivalence for mycophenolate mofetil generics.....	18
10. Recommendations on determination of absolute and relative bioavailability.....	20
11. Clarification on the recommended statistical method for the analysis of a bioequivalence study	21
12. Requirements for demonstration of bioequivalence for generics of biphasic modified release formulations for oral use NEW	33

1. Cocktail studies for investigating *in vivo* drug interaction potential

During the last decade, use of cocktail studies has become a more common tool for investigating a drug's interaction potential *in vivo*. A cocktail study is a study where a number of *in vivo* probe drugs for enzymes (and transporters) are administered together for simultaneous assessment of enzyme/transport activities before and during treatment with another drug. The approach is used for investigating the induction potential *in vivo*, as induction generally affects multiple enzymes and transporters, as well as for studying inhibition of enzymes or transport proteins. Concerns have been raised regarding the validity of cocktail studies, how cocktails should be composed and if the results can be extrapolated to other drugs.

The position of the EWP PK Group on these issues is as follows:

Composition of satisfactory drug cocktails for use in interaction studies

The cocktail should consist of safe, validated probe drugs for the specific enzymes intended to be studied. Preferably, only one enzyme, or one transporter, should be involved in the elimination of each of the included probe drugs. If a second enzyme is catalysing metabolism of the parent drug, its contribution to total clearance should be very small (<10%). The cocktail of probe drugs should have been validated. The validation could have been performed by the applicant or have been published in the scientific literature. The validation of the cocktail includes a validation of the included probe drugs *per se* by investigation of the effect of a selective potent enzyme (or transporter) inhibitor on the pharmacokinetics of the probe drug. In addition, it should also have been verified that the probe drugs used in the cocktail do not affect each others pharmacokinetics. The doses used should preferably be the doses used in the validation. Deviations from this should be justified.

Pharmacokinetic parameters

The use of a cocktail study and conclusions that can be drawn from such a study depends on the objectives of the study and the design and conduct of the study. As in all interaction studies, the dose and duration of the investigational drug should be sufficient for estimating the maximum induction and/or inhibition achieved at a clinically relevant dose. When the objective of the study is to quantify the effect on different enzymes or transporters, it is recommended to determine complete AUCs for the probe drugs in order to estimate effects on (oral) clearance. Simpler ratios such as metabolite to parent drug ratios in urine are usually not a satisfactory parameter as results may have more confounding factors and as the magnitude of an effect is difficult to translate into inhibition or induction potency and to treatment recommendations in the SPC. Additional conventional interaction studies with a probe drug measuring drug clearance may in that case be needed.

Extrapolating results from cocktail studies

If satisfactorily performed, the results of the cocktail studies could be extrapolated to other drugs and to treatment recommendations of the SPC. The extrapolation could then be performed in the same way as from *in vivo* studies using only one probe drug.

2. Requirements for food-interaction studies for modified release formulations

The position of the EWP PK Group is as follows:

a. Guideline recommendations (CPMP/EWP/280/96) and general aspects

Food interactions may be related to the drug substance itself and/or the formulation, the latter being most important in the case of modified release (MR) products.

The aim of food effect studies for new MR formulations (developed either for a new substance or for a substance previously approved in an instant release formulation) is to evaluate the influence of food on the absorption of the drug substance from the new formulation, to evaluate the clinical relevance of a potential food effect and when needed to provide appropriate dose recommendations with respect to intake of the product in relation to meals. This is clearly stated in paragraph 4.1.4.1 of the guideline:

“Different modified release formulations of the same drug substances may differ with respect to food interaction. Hence, the influence of food on the bioavailability of oral modified release formulations must be investigated for safety and efficacy purposes.

The optimal experimental conditions to produce a food effect include the ingestion of a predefined high fat meal immediately before dosing. For the assessment of food effects besides AUC and C_{max}, it may also be valuable to compare the modified release characteristics.

If a significant food effect is found, applicant should give a justified dose recommendation with respect to the intake of the product in relation to meals.

Possible approaches for the investigation of the effect of food on the bioavailability of modified release forms reflecting the present scientific approach are presented in Annex 1. However, due to the complexity of the food-drug interaction with any particular dosage form a different approach for in vivo studies can be accepted if adequately justified.”

Food effect studies for new MR formulations should be conducted early during drug development so that appropriate recommendations regarding intake in relation to food can be included in clinical efficacy and safety studies.

In contrast to new MR formulations, for **generic MR products** bioequivalence under fed conditions is required rather than the investigation of food interaction as described in paragraph 4.1.4.1, i.e.

- paragraph 5.1 reg. prolonged release formulations states that *“the effect of food on the in vivo performance is comparable for both formulations when a single dose study is conducted comparing equal doses of the test formulation with those of the reference formulations administered immediately after a predefined high fat meal. This study should be conducted with the same strength as those of the pivotal bioequivalence studies.”*
- paragraph 5.2 regarding delayed release formulations states that *“As food can influence the absorption of an active substance administered in an enteric-coated formulation, post-prandial bioequivalence studies are necessary.”*

It has been shown that food composition (fat content) and timing may be crucial for drug product bioavailability. Administration immediately after completing a high fat meal serves as kind of “worst case” situation in terms of product performance/robustness. Therefore, a food interaction study should be performed accordingly.

Section 4.1.5.1 of the guideline states

If the modified release formulation contains a higher dose compared to the approved immediate release product, the possibility of unexpected release resulting in unacceptable higher exposure should be excluded.

One issue that is important to consider for both new MR formulations and generic MR formulations is the influence of alcohol on the MR formulation and the risk for unexpected release caused by alcohol ingestion.

b. Study design - Guideline recommendations (CPMP/EWP/280/96) based on App. 1

Appendix 1 of the guideline provides recommendations regarding study design in different scenarios. Some explanation and comments to these recommendations are given below.

Bioanalytical measurements should include quantification of metabolites or enantiomers if respective requirements apply.

1. MR formulation developed for a New Chemical Entity (NCE)

For MR formulations developed for an new chemical entity the guideline recommends a single dose 4 way crossover study ; MR fed and fasted + oral solution (or immediate release (IR) formulation if a solution is not feasible) fed and fasted. With this study design the effect of food on both the substance and the MR formulation can be evaluated.

However section 4.1.4.1 of the guideline also states that a different approach for in vivo studies can be accepted if adequately justified. Hence, a 2-way cross over study (MR formulation fasting and fed) could be sufficient to evaluate the formulation related food effect.

The guideline also states that a single dose 3 way crossover study may be required in case the clinical trial formulation differs from the to-be-market product; i.e. comparing clinical trial formulation fasted with to-be-marketed formulation fed and fasted. However, if there is a marked food effect on the clinical trial formulation and the formulation has been taken under non-fasting conditions in the clinical studies, it may be advantageous to have comparative data on the food-effect on the marketing formulation in the same study, i.e. also here a 4-way crossover study with clinical trial and marketing formulation under fasting and fed conditions. This information may be important in the evaluation of dosing recommendations.

In case there is a marked food-effect, additional food-interaction studies might be needed to support dosing recommendations, i.e. studies of the effect of different kinds of food, studies investigating the effect of a meal taken at certain time period before and after the drug, etc.

2. MR formulation developed after an approved IR formulation

The guideline recommends a single dose 3 way crossover study; MR fed and fasted + IR fasted. However, the design of this study depends on which other studies that are conducted comparing the new MR formulation with the approved IR formulation and if there is a clinically significant food effect on the IR formulation. If there is no food effect on IR formulation, a 2-way cross-over study comparing MR formulation fasted and fed could be sufficient (given that other studies compare the MR and IR formulation under fasting conditions). In case of a clinically significant food effect for the IR formulation, a 4-way cross-over study comparing MR formulation fasted and fed and IR formulation fasted and fed could be useful to quantify the food effect on each formulation. If a 3-way cross-over study is conducted with IR formulation in one arm, consideration should be given to whether the IR formulation should be taken fasted or in a fed state (i.e. intake in accordance with the recommendation in the SPC).

3. *MR formulations developed as generics*

For generic products, the guideline recommends two single dose 2 way crossover studies evaluating test and reference fasted, and test and reference fed, respectively. Alternatively a single dose 4 way crossover study (MR generic fed and fasted + reference fed and fasted) can be conducted to demonstrate bioequivalence between generic and reference in both fasting and fed state. In a 4 way crossover study a comparison of the food effect for test and reference is possible, which will not be the case if two 2 way cross over studies are conducted, as between study comparison of food effect is not recommended.

For both single-unit formulations and multiple-unit formulations, the highest strength should in general be studied. In case a non-linearity in the food effect is suspected, the food interaction study should be performed with the highest and the lowest strength.

c. Defining a "high fat meal"

Presently, the guideline on modified release formulations does not give any advise regarding the type of meal, but the composition of a 'high fat meal' meal is recommended in the revised Guideline on the Investigation of Bioequivalence (CPMP/QWP/EWP/1401/98 Rev. 1) as follows:

...the meal should be high fat (approximately 50 percent of total caloric content of the meal) and high-calorie (approximately 800 to 1000 kcal) meal. This test meal should derive approximately 150, 250, and 500-600 kcal from protein, carbohydrate, and fat, respectively. The composition of the meal should be described with regard to protein, carbohydrate and fat content (specified in grams, calories and relative caloric content (%)).

d. Evaluation

Evaluation of food study results includes metabolites or enantiomers in case respective requirements apply.

New MR formulations

For MR formulations developed for a NCE or MR products developed after an approved IR formulation the food interaction study will provide quantitative data on the extent of influence of food on the pharmacokinetics. The clinical relevance of the effect of food should be discussed both from an efficacy and a safety perspective. When needed dose recommendations with respect to intake of the product in relation to meals should be given. Additional studies with other types of food, or with intake of the drug at certain time intervals before and after a meal may be needed to support the proposed dose recommendations.

Generic MR formulation

The bioequivalence approach considering usual acceptance limits (80 – 125 %) is applicable for generic MR products. If bioequivalence between generic and reference has been demonstrated both in fasting and in fed state the MR generic product and the reference can be considered to behave similar under fed conditions.

Any widening of the acceptance criteria for C_{max} should follow the recommendations of the revised guideline on the investigation of bioequivalence (CPMP/EWP/QWP/1401/98 rev 1).

For delayed release formulations with single unit dosage forms differences in t_{max} is also recommended to be assessed, especially for products where a fast onset of action is important.

e. Special cases

1. Can a MR product be considered a generic if it has no food-effect as opposed to the innovator which has one?

In general a generic is meant to be bioequivalent with the innovator under fasted and fed conditions. A difference regarding formulation related food interactions indicates product differences thus contradicting the generic by definition. Accordingly, for products where bioequivalence can be shown in the SPC recommended condition but not in the non-recommended state due to a different food effect, the product does not fulfil the requirements of a generic product, but could be eligible for an Article 10(3) application.

2. What studies are needed for a generic if the innovator's SPC states that it should be taken with a meal only or only in the fasted state?

Comparative studies should be performed under both fed and fasted conditions. See also response above.

Since the guideline on modified release formulations (CPMP/EWP/280/96) is currently under revision certain requirements may be changed with a revised document.

3. Bioequivalence studies in children

The EWP-PK subgroup was asked to address the following questions: "Treatment of children often requires that new formulations or strengths are developed. If chemical-pharmaceutical data are not considered sufficient to establish bioequivalence should bioequivalence studies be conducted in children or would healthy volunteers suffice?"

The position of the EWP-PK subgroup is as follows:

In vivo bioequivalence is almost always established in healthy volunteers unless the drug carries safety concerns that make this unethical. This model, *in vivo* healthy volunteers, is regarded adequate in most instances to detect significant formulation differences and the results will allow extrapolation to populations in which the drug is approved (the elderly, patients with renal or liver impairment etc). The same reasoning applies also to children. Hence, in the vast majority of cases BE studies in healthy volunteers are adequate for products intended for use in children.

4. Bioequivalence of gastro-resistant preparations (e.g. omeprazole)

The EWP-PK subgroup was asked to address the following question: "What are the recommendations for demonstration of bioequivalence of gastro-resistant preparations (e.g. omeprazole)?"

The position of the EWP-PK subgroup is as follows:

General aspects:

According to section 5.2 Delayed release formulations of the Note for Guidance on Modified Release Oral and Transdermal Dosage Forms (CPMP/EWP/280/96), in gastro-resistant or enteric products bioequivalence should be demonstrated not only in a single dose study in fasted conditions, but also in a single dose study under fed conditions. The fed study should be conducted using a high-fat meal (approximately 50 percent of total caloric content of the meal) and high-calorie (approximately 800 to 1000 kcal) meal. This test meal should derive approximately 150, 250, and 500-600 kcal from protein, carbohydrate, and fat, respectively. The composition of the meal should be described with regard to protein, carbohydrate and fat content (specified in grams, calories and relative caloric content (%)).

Consequently, bioequivalence studies should be performed under both fed and fasting conditions. In general a generic is meant to be bioequivalent with the innovator under fasted and fed conditions. A difference regarding formulation related food interactions indicates product differences thus contradicting the generic by definition. Accordingly, for products where bioequivalence can be shown in the SPC recommended condition but not in the non-recommended state due to a different food effect, the product does not fulfil the requirements of a generic product, but could be eligible for an Article 10(3) application. See also section 2 "Requirements for food-interaction studies for modified release formulations" for recommendations regarding study design, etc.

Gastric emptying of single unit dosage forms non-disintegrating in the stomach (e.g. enteric coated tablets) is prolonged and highly erratic, most likely due to the effect of the inter-digestive cycle within the Migrating Myoelectric Complex. The consequences of this effect on the enteric coating of delayed release formulations are largely unpredictable: if e.g. the active pharmaceutical ingredient (API) release occurs prior to stomach emptying because of prolonged residence in the stomach either degradation can occur or the release may be considerably delayed. In either case erratic concentration profiles (either non-existing or extremely delayed) can be obtained. Therefore the sampling period should be designed such that measurable concentrations are obtained, taking into consideration not only the half-life of the drug but the possible occurrence of this effect as well. This should reduce the risk of obtaining incomplete concentration-time profiles due to delay to the most possible extent. These effects are highly dependent on individual behaviour. Therefore, but only under the conditions that sampling times are designed to identify very delayed absorption and that the incidence of this outlier behaviour is observed with a comparable frequency in both, test and reference products, these incomplete profiles can be excluded from statistical analysis provided that it has been considered in the study protocol.

The general requirements for biowaiver of an additional strength detailed in section 4.1.6 of the Guideline on the investigation of bioequivalence (CPMP/EWP/QWP/1401/98 rev 1) are applicable also for delayed release tablets and recommendations regarding which strength to study is given in the same section of this guideline and also in section 2 "Requirements for food-interaction studies for modified release formulations". When evaluating proportionality in composition, it is recommended to consider the proportionality of gastro-resistant coating with respect to the surface area (not to core weight) to have the same gastro-resistance (mg/cm^2).

The dissolution profiles should be compared not only in Pharmacopoeial conditions (2 hours at pH 1.2 followed by 45 minutes at pH 6.8), but also at more neutral pHs in the range 2-5, both for single unit non disintegrating and disintegrating dosage forms with multiple units. Hence, at least, two dissolution tests in two steps are required. First a comparison at pharmacopoeial conditions, 2 hours at pH 1.2 followed by 45 minutes in pH 6.8 and then a second separate dissolution test at a higher initial pH mimicking fed state e.g. 2 hours at 4.5 followed by 45 minutes in pH 6.8.

Concluding similarity if dissolution of more than 85% is obtained within 15 minutes is not applicable for gastro-resistant formulations. In case of gastro-resistant formulations the release occurs after gastric emptying (median approx. 13 – 15 min). Therefore, the comparison of dissolution profiles should be performed even if dissolution is more than 85% before 15 min in either products or strengths. Hence, a tight sampling schedule is recommended after the product has been investigated for 2 h in media mimicking the gastric environment (pH 1.2 or 4.5) since profile comparison (e.g. using the f₂ calculation) is required.

5. Bioequivalence studies for generic products containing clopidogrel

The platelet aggregation inhibitor clopidogrel is pre-systemically hydrolysed to the inactive metabolite clopidogrel carboxylic acid. The plasma levels of the unchanged drug are up to 2000 fold lower than those of the carboxylic acid metabolite. Another metabolite, clopidogrel thiol, formed by a parallel pathway, is the pharmacologically active form of clopidogrel and is generated in the intestine and liver primarily by the CYP2C19 enzyme isoform. Due to its chemical instability and low circulating levels, its detection in plasma is problematic. Clopidogrel thiol irreversibly binds to the P2Y₁₂ receptors of ADP on the platelet membranes in portal and systemic circulation, leading to the inhibition of platelet aggregation.

During the evaluation of the Marketing Authorisation applications for generic product of clopidogrel, the following questions were addressed by the CHMP to the EWP-PK subgroup and the EWP-CVS subgroup group¹, respectively:

1. Which substance should be studied in bioequivalence studies: the parent compound clopidogrel or the metabolite(s) of clopidogrel?

The *Guideline on the investigation of bioequivalence* (CPMP/EWP/QWP/1401/98 Rev 1) states "Also for inactive prodrugs, demonstration of bioequivalence for parent compound is recommended. The active metabolite does not need to be measured."

At the time of approval of the reference product Plavix, no reliable and validated methodology for the determination of the pharmacokinetics of the parent prodrug clopidogrel or of the active metabolite clopidogrel thiol was available. Thus, at the time, the pharmacokinetic profile of clopidogrel was established based on the pharmacokinetics of clopidogrel carboxylic acid, which is the non-active metabolite. In the meantime, the pharmacokinetic profile characterisation of clopidogrel has improved by development of a sensitive analytical technique (e.g. LC-MS-MS) enabling for a suitable investigation of the parent prodrug, clopidogrel. A more accurate picture of the PK profile of clopidogrel can be obtained.

Position of the EWP-PK subgroup:

The demonstration of bioequivalence between the reference and the generic compound should be based on the parent prodrug, clopidogrel.

2. Is demonstration of bioequivalence under fed conditions necessary in addition to the demonstration under fasting conditions?

At the time the innovative drug-product was developed, no data regarding the effect of food on the bioavailability of clopidogrel parent compound were available. More recently, the investigation of food intake influence on the bioavailability of clopidogrel has been investigated. The results obtained by Nirogi *et al.* (Nirogi, RV *et al.*, *Arzneimittelforschung* 2006; 56(11); 735-9: *Effect of food on bioavailability of a single oral dose of clopidogrel in healthy male subjects*) indicate that in the fed state the bioavailability of a single oral dose of clopidogrel increases dramatically (500 - 600 %) but the systemic exposure to the major but inactive carboxylic acid metabolite increases only by approximately 10-20 %. The current Summary of Product Characteristics (SPC) for the originator states that clopidogrel should be given as a single daily dose of 75 mg with or without food.

¹ EWP Therapeutic Subgroup on Cardiovascular Issues

Position of the EWP-PK subgroup:

The Guideline on the investigation of bioequivalence (CPMP/EWP/QWP/1401/98 Rev 1) states “*In general, a bioequivalence study should be conducted under fasting conditions as this is considered to be the most sensitive condition to detect a potential difference between formulations. For products where the SmPC recommends intake of the reference medicinal product on an empty stomach or irrespective of food intake, the bioequivalence study should hence be conducted under fasting conditions.*”

The food effect on the bioavailability (BA) of the unchanged clopidogrel - not recognised in the SPC - was not investigated by the innovator before approval of the originator product since a sensitive analytical method was not available at the time of approval. However, a publication by Nirogi et al. (2006) suggested a significant food effect with a high-fat meal. Similar results have been observed in applications for generic medicinal products. The food effect might be due to a protection from acidic hydrolysis in the stomach in a fasting state, since the BA is enhanced under fed conditions. The EWP-PK subgroup reviewed the solubility properties of clopidogrel salts and these indicate that when administration of clopidogrel occurs under fasting conditions, the dissolution in the gastric media with a subsequent hydrolysis and formation of the inactive carboxy-acid metabolite is maximal. As a consequence, the extent of unchanged drug that still is available for absorption (at the intestine level) is reduced. Conversely, the dissolution of clopidogrel is limited in the gastric media under fed conditions, the acidic hydrolysis in the stomach is reduced and the BA of clopidogrel is improved.

The EWP-PK subgroup acknowledges that as a consequence, the solubility of salts might be important. However, all clopidogrel salts have high solubility at low pH and the risk for acidic hydrolysis may therefore be similar. The food effect could consequently be expected to be similar to the reference product for different salts. Hence, the EWP-PK subgroup considered that there was currently an insufficient scientific rationale to justify a deviation from the revised bioequivalence guideline and bioequivalence should be demonstrated under fasting conditions irrespective of the salt.

Should further information on the food effect of clopidogrel become available, the SPC would be amended accordingly.

3. Bioanalytical methods: Should there be any special requirements to ensure that the risk of back-conversion of the major metabolite to clopidogrel could be excluded?

Within several centralised clopidogrel applications, the CHMP raised concerns about the possible back-conversion of the major metabolite of clopidogrel (clopidogrel carboxylic acid) to clopidogrel during the bio-analytical analysis of the samples. Considering that plasma levels of clopidogrel carboxylic acid observed in patients or healthy volunteers treated with clopidogrel are much higher than that of the parent drug, a minimum back-conversion of the metabolite could potentially lead to a huge over-estimation of clopidogrel plasma levels and would bias the outcome of bioequivalence study.

Position of the EWP-PK subgroup:

The EWP-PK subgroup confirmed that back-conversion could potentially occur when methanol is used as (part of) extraction solvent, reconstitution solvent, chromatography mobile phase or for the preparation of calibrators, quality control (QC) solutions and internal standards during bioanalysis. Therefore, testing for the back-conversion of clopidogrel carboxylic acid metabolite should be part of the validation process of analytical methods used for the measurement of clopidogrel plasma levels.

It should be demonstrated that there is no back-conversion of the major metabolite to the parent drug clopidogrel under all conditions for sample handling (including extraction procedures) and storage.

4. Could the acceptance criteria for C_{max} be widened?

According to the *Guideline on the investigation of bioequivalence* (CPMP/EWP/QWP/1401/98 Rev 1) widening of the acceptance criteria for C_{max} is possible for highly variable drug products provided that a wider difference in C_{max} is considered clinically irrelevant based on a sound clinical justification. The revised bioequivalence guideline provides detailed advice on how the acceptance criteria can be widened for highly variable drug products with a bioequivalence study of replicate design and using the scaled-average-bioequivalence approach. However, a prerequisite for widening the acceptance criteria is that a wider difference in C_{max} is considered clinically irrelevant. This issue was assessed by the EWP-CVS subgroup.

Position of the EWP-CVS subgroup:

The EWP-CVS subgroup evaluated the request from widening the 90% confidence interval for C_{max} from the efficacy and safety perspectives. The EWP-CVS subgroup considered what would be the degree of the impact of the possible variations in the C_{max} following the 75 mg dose, since some data suggest the existence of a plateau response in the inhibition of platelets aggregation. However, it is currently not entirely clear what would be the influence of variable clopidogrel concentrations on pharmacodynamics. It is important to note that clopidogrel is approved and recommended for use in acute clinical conditions, for which a high loading dose is advised in order to attain a fast antiplatelet action. Whether in these situations a lower C_{max} might be of clinical relevance is unknown, but cannot be completely excluded.

In conclusion, it is not definitely proven that widening C_{max} acceptance range for clopidogrel is devoid of clinically relevant implications, both in terms of safety and efficacy, for all situations where the drug is used in clinical practice. Under these circumstances, the widening of 90% confidence intervals for C_{max} is not recommended.

6. Acceptance criteria for bioequivalence studies for losartan

The EWP-PK subgroup was asked to address the following question: Which analyte, parent and/or metabolite, should be used for the decision of bioequivalence in the case of losartan, and which acceptance criteria should be applied.

Position of the EWP-PK subgroup:

Losartan is not a pro-drug. It is an angiotensin II antagonist at the AT1-subtype receptor. In humans, losartan competitively binds to the AT1 receptor, while the metabolite E3174 binds non-competitively.

The active metabolite E3174 is not directly formed from losartan, but from an intermediate product, metabolite E3179. Alternatively, the E3179 intermediate can also be hydroxylated to an inactive metabolite. It has been estimated that about 14% of the orally administered losartan dose is converted into E3174. In addition, 5 other minor metabolites exist that exhibit activity but much less than parent.

AUC of the active metabolite is 4 – 8 fold higher than parent, as it is cleared about 10-fold slower than parent.

Plasma free fractions of parent are 1.3% and that of the active metabolite 0.2%. Losartan and its metabolite E3174 shows linear pharmacokinetics.

It has been shown in vitro that the IC50 for binding to the AII receptor in smooth muscle cells is 10-fold more potent for the metabolite than parent and that the in vitro AII concentration dependent contractile response in rabbit aorta is 33-fold higher for the metabolite. In vivo, in normotensive and renal hypertensive rats, the active metabolite has been shown to be 15 – 20-fold more potent compared to the parent.

Based on in vivo studies in rat, in which the potency was 15 – 20-fold higher for the metabolite, and assuming a more or less comparable protein binding as that observed for human plasma (literature indicated for losartan a binding >99% in rat plasma), the metabolite activity is about 76 – 100-fold higher than the parent compound.

Hence, based on total exposure (AUC), the metabolite accounts for the majority of the activity. However, losartan and the active metabolite have different plasma-concentration time course, with considerably higher losartan plasma concentrations during the first hours after administration. Considering the plasma concentration time course, difference in activity and protein binding, losartan may account for a large part of the activity during the first hour after the first drug administration, and at losartan t_{max} , which occur after about one hour, contribution to activity may be almost equal for losartan and the metabolite. Thereafter, the metabolite's contribution to activity is much larger.

Moreover, as the active metabolite E3174 is formed via an intermediate product and not direct from the parent, the pharmacokinetic data for metabolite E3174 may not reflect the rate of absorption of parent.

Therefore, bioequivalence for losartan should be proven based upon parent data. Regarding what acceptance criteria to apply, the submitted documents do not allow any conclusion to be drawn on this and consequently a conservative approach using 90% CI of 80 – 125% for AUC and C_{max} applies.

7. Bioequivalence assessment of generics for tacrolimus

In relation to the bioequivalence guideline, which has been drafted by the EWP-PK subgroup, a question was raised regarding the assessment of bioequivalence for tacrolimus generic products. There were different views whether the normal (80-125%) or a tightened (90-111%) acceptance range for the 90% CIs, for both AUC and C_{max}, should be applied.

The decision on the bioequivalence criteria requires the clinical judgement whether tacrolimus is considered a narrow therapeutic index drug (NTID). Therefore, the response to this question has been prepared by the Efficacy Working Party (EWP) taking the EWP-PK's general position on bioequivalence criteria for NTIDs into account.

The position of the EWP is as follows:

The decision on whether a particular active substance may be considered to be a narrow therapeutic index drug (NTID), and whether narrowing of the bioequivalence acceptance limits should apply, needs to be based on clinical considerations of the dose- or concentration-response relationships for both efficacy and safety.

The following key issues are identified for tacrolimus:

- Tacrolimus is a drug that requires individual dose titration to achieve a satisfactory balance between maximizing efficacy and minimizing serious dose related toxicity. Plasma level monitoring is routinely employed to facilitate dose titration.
- Recommended Therapeutic Drug Monitoring schemes often set desirable levels close to the upper or lower limit of the therapeutic window (5 ng/ml or 20 ng/ml), for example the use of "minimisation protocols" using low levels during maintenance phase. It is well established from clinical experience with the drug that even small changes of dose can lead to crossing the upper or lower limits of the therapeutic window
- In the case of kidney and heart transplantation, there is only a two fold difference in the upper and lower limit of the proposed therapeutic range (whole blood levels from 10 to 20 ng/mL). This is comparable to the therapeutic range for "classical" NTIDs such as digoxin.
- The consequences of over-dosing and of under-dosing (including morbidity/mortality associated with graft rejection) are of major clinical importance and can substantially affect clinical outcome.

For the above reasons the EWP considers that tacrolimus is a drug with a narrow therapeutic index.

In a number of EU countries generic prescribing is the norm and pharmacies may dispense either the branded product or a generic. Where multiple generics are available patients may be switched from one generic to another when renewing their prescription. Changes of formulation in this situation would not normally be accompanied by re-titration. The usual frequency of whole blood drug level measurements in clinical practice (typically once per month during maintenance phase) is not sufficiently frequent to ensure avoidance of over or under dosing as a result of a patient switching to a different formulation in the event of generic substitution of tacrolimus. Therefore, in order to ensure the safety and efficacy of generic tacrolimus products it is necessary to apply tighter bioequivalence acceptance criteria than the conventional 80-125%.

The EWP discussion also covered whether the narrowing of the bioequivalence acceptance criteria to [90-111%] can be limited to AUC and will not be needed for C_{max} . For tacrolimus, this is supported by the following PK and PK/PD characteristics. Total drug exposure (AUC) is considered to be the key parameter of importance for dose titration of tacrolimus; in comparison peak whole blood levels do not seem to be critical for either safety or efficacy. As tacrolimus has a long elimination half life C_{min} trough levels can be used as a surrogate for AUC in clinical practice. Given the long terminal half-life, tacrolimus accumulates during repeated dosing. Due to this accumulation, a potential difference between formulations in C_{max} after single dosing can be expected to be less at steady state, if AUC is the same for the two formulations. Therefore, the normal acceptance criteria for C_{max} [80-125%] can be used in single dose bioequivalence studies for tacrolimus.

Conclusion: The EWP recommends that the bioequivalence acceptance criteria for tacrolimus should be [90-111%] for AUC and [80-125%] for C_{max} .

8. Requirements for demonstration of bioequivalence for ciclosporine generics

The reference product Neoral soft gelatine capsule concerns a specific formulation of ciclosporin which undergoes microemulsification process at administration (in the presence of water). For Neoral, the SmPC indicates a 26% decrease in C_{max} and a 15% decrease in AUC, in case the product is taken with a high fat meal.

As indicated in the guideline on bioequivalence (CPMP/EWP/QWP/1401/98 Rev 1.), for products with specific formulation characteristics, like Neoral, bioequivalence studies performed under both fasted and fed conditions are required unless the product must be taken only in the fasted state or only in the fed state. Neoral may be taken with or without food, and in clinical practice, ciclosporin is often recommended to be taken in a standardised way in relation to food. Hence, a generic ciclosporin product must be bioequivalent with the originator product both in fasting and in fed state.

As EWP has defined ciclosporine to be a NTID, for which both AUC and C_{max} are important for safety and efficacy, a narrowed (90.00-111.11%) acceptance range should be applied for both AUC and C_{max}, under fasting as well as under fed conditions, in line with the guideline on bioequivalence (CPMP/EWP/QWP/1401/98 Rev 1.).

Although a generic product with a reduced food effect could be considered an improvement, this would not be considered acceptable for a 'generic application', but could be considered for a "hybrid" application, article 10(3) with additional data to support an application under this legal basis.

9. Requirements for demonstration of bioequivalence for mycophenolate mofetil generics

The CMDh requested from the PKWP a position concerning interpretation of the revised Guideline on the Investigation of Bioequivalence with respect to the bioequivalence data for inactive pro-drugs in relation to both parent drug and metabolite in the context of demonstration of bioequivalence for mycophenolate mofetil.

The questions relate to the circumstances under which it is acceptable to base bioequivalence decision solely on metabolite data if a pro-drug plasma level is measurable. The revised guideline states: "*Also for inactive pro-drugs, demonstration of bioequivalence for parent compound is recommended*".

- 1) If the exact meaning of the word "*recommended*" in the context of mycophenolate mofetil (MMF), depends on
 - either the feasibility of the technical detection limits, in which the concentrations of the inactive prodrug are approximately 12000- to 6000-fold lower, for AUC and C_{max} , respectively, than that of the active metabolite mycophenolic acid.
 - or should specific PK-parameters be taken into account, low exposure of the parent resulting in a short T_{max} , which makes it not relevant to measure the parent drug.

Position of the PKWP:

The bioequivalence guideline states "*for inactive prodrugs, demonstration of bioequivalence for parent compound is recommended*". The guideline further clarifies: "*However, some pro-drugs may have low plasma concentrations and be quickly eliminated resulting in difficulties in demonstrating bioequivalence for parent compound. In this situation it is acceptable to demonstrate bioequivalence for the main active metabolite without measurement of parent compound.*" Hence, although the guideline recommends the use of parent compound also for inactive pro-drugs, exceptions are possible. The acceptability of use of main active metabolite instead of parent compound will be determined based both on the feasibility of measuring parent compound and on the pharmacokinetic characteristics for parent compound and active metabolite. For pro-drugs with a very large difference in exposure between parent and active metabolite and where the pro-drug is quickly eliminated, it is expected that there can be difficulties in demonstrating bioequivalence for parent compound and demonstration of bioequivalence based on active metabolite alone can be accepted.

For mycophenolate mofetil (MPM) specifically, the parent compound undergoes extensive presystemic metabolism to the active metabolite MPA. Moreover, MPM half-life is very short (0.60 to 1.20 h as reported) resulting in approximately 12000- and 6000-fold lower AUC and C_{max} respectively, for parent compound compared to metabolite. MPM has a t_{max} of 0.5 h and a $t_{1/2}$ of less than 1 h, which limits the characterisation of the early plasma concentrations. As a consequence reliable estimation of C_{max} will be difficult. "*In this situation it is acceptable to demonstrate bioequivalence for the main active metabolite without measurement of parent compound*" as stated in the bioequivalence guideline.

- 2) Is it acceptable NOT to follow this recommendation and use ONLY metabolite data to demonstrate bioequivalence between two products of the same pro-drug mycophenolate mofetil, even when current analytical assays allow measuring the parent with acceptable sensitivity?

Position of the PKWP:

A recommendation leaves room for an exceptional decision on a case by case basis. In this case it is clear that the parent compound is inactive and completely converted into the active metabolite yielding a 12000 fold difference in AUC. Due to this, demonstration of bioequivalence between two products of the same pro-drug can be based on metabolite data only. The argument that current analytical assays allow measuring the parent with acceptable sensitivity cannot be readily taken considering the short t_{max} and $t_{1/2}$ of the parent compound which will limit a reliable estimation of C_{max} of the parent compound.

10. Recommendations on determination of absolute and relative bioavailability

Absolute bioavailability

Information on absolute bioavailability is important in the overall evaluation of the pharmacokinetics of the drug substance. For some new chemical entities information on absolute bioavailability facilitates the evaluation of the mass balance study, and enables conclusions regarding the contribution of different elimination routes to drug clearance. This information is important when determining the need for studies in subjects with renal and hepatic impairment as well as the need for drug-drug interaction studies at biliary excretion level. The information is also useful when predicting the consequences of pre-systemic drug-drug interactions, both at absorption and metabolism level. Therefore, for new active substances intended for systemic action, the absolute bioavailability should, if possible, be determined by comparing the bioavailability of the intended pharmaceutical form for an extra-vascular route of administration with an intravenous administration. For substances with non-linear pharmacokinetics, consideration should be given to the dose(s) used for evaluation of absolute bioavailability. Furthermore, data on absolute bioavailability is valuable in the evaluation of BCS based biowaivers (see Guideline on the investigation of bioequivalence, CPMP/EWP/QWP/1401/98 Rev. 1).

Relative bioavailability

It is recommended to obtain information on the relative bioavailability of different dosage forms (or formulations) used during drug development. By definition relative bioavailability is the comparison of different dosage forms (or different formulations thereof) administered by the same or a different non-intravenous route (e.g. tablets vs. oral solution).

Regarding formulation changes during drug development, unless BCS based biowaiver is applicable bioequivalence studies are needed if there has been a change between the formulation used in phase III and the final marketing formulation which may affect rate or extent of absorption. Relative bioavailability studies (or comparative bioavailability studies) are recommended between different formulations used during phase I, II and III. There is no requirement for demonstration of bioequivalence between phase II and phase III formulations. It is assumed that any difference in rate or extent of absorption between these formulations is taken into account in the design of the phase III studies. The clinical relevance of any differences in exposure between formulations used in phase I, II and III studies should be discussed in applications for NCEs in Module 2.5 and 2.7.1 and taken into account in the assessment of pharmacokinetic data in Module 2.7.2.

Recommendations for Suprabioavailable products

A suprabioavailable product displays appreciably larger extent of absorption than an approved reference medicinal product.

If suprabioavailability is found, development of a lower dosage strength should be considered. In this case, the biopharmaceutical development should be reported and a final comparative bioavailability study comparing the reformulated new product with the approved reference medicinal product should be submitted. The potential for a difference in food effect on the rate and/or extent of absorption or a difference in absorption interactions between the reformulated new product and the approved reference product should be discussed and when relevant evaluated in vivo.

In case a lower dosage strength has not been developed the dosage recommendations for the suprabioavailable product will have to be supported by clinical studies.

11. Clarification on the recommended statistical method for the analysis of a bioequivalence study

1. Introduction

The following text on the general analysis of bioequivalence studies is included in the guidance document. The bold text is the main sentence of interest for this discussion.

4.1.8 Evaluation

Statistical analysis

The assessment of bioequivalence is based upon 90% confidence intervals for the ratio of the population geometric means (test/reference) for the parameters under consideration. This method is equivalent to two one-sided tests with the null hypothesis of bioinequivalence at the 5% significance level.

The pharmacokinetic parameters under consideration should be analysed using ANOVA. The data should be transformed prior to analysis using a logarithmic transformation. A confidence interval for the difference between formulations on the log-transformed scale is obtained from the ANOVA model. This confidence interval is then back-transformed to obtain the desired confidence interval for the ratio on the original scale. A non-parametric analysis is not acceptable.

The precise model to be used for the analysis should be pre-specified in the protocol. The statistical analysis should take into account sources of variation that can be reasonably assumed to have an effect on the response variable. The terms to be used in the ANOVA model are usually sequence, subject within sequence, period and formulation. **Fixed effects, rather than random effects, should be used for all terms.**

Following the publication of revised version of the Guideline on the Investigation of Bioequivalence (CPMP/QWP/EWP/1401/98 Rev.1) this paragraph raised several questions from interested parties. The reason for this interest was twofold. Firstly, the new guideline gives more emphasis to replicate design trials and evaluation of such trials is a more complex task compared to a conventional two-period two sequence crossover trial. Secondly, the current standard for the analysis of replicate design trials is a likelihood-based linear mixed model with random subject effects.

The question of whether to use fixed or random effects is not important for the standard two period, two sequence (2×2) crossover trial. In section 4.1.8 of the guideline it is stated that "subjects in a crossover trial who do not provide evaluable data for both of the test and reference products should not be included." Provided this is followed the confidence intervals for the formulation effect will be the same regardless of whether fixed or random effects are used.

Therefore all that remains to be discussed is the analysis method for replicate designs. In section 2 three models for analysing data from replicate bioequivalence trials are considered. To illustrate these approaches, in section 3 data from a four-period unbalanced study (see data set I) and data from a three-period balanced study (data set II) were analysed using different statistical models and computer programs.

2. Studied methods

2.1 Approach compatible with CHMP guideline (Method A)

The approach envisaged when the current guideline was written was to simply use the same analysis method for replicate designs as is used for 2x2 trials.

```
proc glm data=replicate;
class formulation subject period sequence;
model logDATA= sequence subject (sequence) period formulation;
estimate "test-ref" formulation -1+1;
test h=sequence e=subject(sequence);
lsmeans formulation / adjust=t pdiff=control("R") CL alpha=0.10;
run;
```

For this model there is only one variance term estimated, σ_w^2 , the within subject variability.

2.2. Slight modification to approach compatible with CHMP guideline (Method B)

The same model as specified above could be used in PROC MIXED and subject specified as a random effect.

```
proc mixed data=replicate;
class formulation subject period sequence;
model logDATA= sequence period formulation;
random subject(sequence);
estimate "test-ref" formulation -1 1 / CL alpha=0.10;
run;
```

This means there are two variance terms estimated σ_w^2 and σ_b^2 , as a distribution is also fitted to the between subject variability. If subject is a fixed effect (as in the previous model) each subject is treated as being selected in some way rather than being sampled from a random distribution and a subject effect is estimated individually for each patient as is done for the period effect.

This model will give the same results as Method A if all subjects included in the analysis provide data for all treatment periods.

2.3. Method C

The FDA Guidance for Industry document "Statistical approaches to establishing bioequivalence" specifies the code to be used for the analysis of replicate designs using PROC MIXED.

```
proc mixed data=replicate;
classes sequence subject period formulation;
model logDATA= sequence period formulation / ddfm=satterth;
random formulation/type=FA0(2) sub=subject G;
repeated/grp=formulation sub=subject;
estimate 'test-ref' formulation -1 1/ CL alpha=0.10;
run;
```

This model allows a different subject effect for each formulation (i.e. a subject by formulation interaction), and therefore has 5 variance terms (within subject for reference, within subject for test, between subject for test, between subject for reference, covariance for between subject test and reference – the last three are combined to give the subject x formulation interaction variance component.)

This model will provide the same point estimate as methods A and B if all subjects provide data for all treatment periods. However it will generally give wider confidence intervals than those produced by methods A and B.

3. Results

3.1. Data set I

The following data reflect a four period crossover study where subjects receive both test and reference twice, with some subjects providing data for only a subset of the treatment periods. Results obtained with methods A, B and C are shown in the following table.

	Point estimate	90% confidence interval
Method A (guideline recommended)	115.66	107.11, 124.89
Method B (random effects)	115.73	107.17, 124.97
Method C (random effects with interaction)	115.66	107.10, 124.89

Within subject CV% (from method C) – reference 47.3%, test 35.3%

The results are generally very similar although missing treatment periods for some subjects causes the results to be different for all three approaches.

3.2. Data set II

Data of a three period crossover study where all subjects receive reference twice and test once were analyzed using Methods A, B and C.

The results are given in the Table below

	Point estimate	90% confidence interval
Method A (guideline recommended)	102.26	97.32, 107.46
Method B (random effects)	102.26	97.32, 107.46
Method C (random effects with interaction)	102.26	97.05, 107.76

Within subject CV% (from method C) – reference 11.5%

As there are no subjects with missing treatment periods the results from methods A and B are identical, and the point estimate is the same for all three approaches. Method C gives wider intervals.

3.3. Alternative computer programs

SAS (version 9.1, SAS Institute Inc, NC) was used in the previous computations. Results obtained by alternative, validated statistical programs are also acceptable except spreadsheets because outputs of spreadsheets are not suitable for secondary assessment.

3.4. Estimating the within subject variability

The guideline introduces the possibility of widening the acceptance limits for C_{max} if the within-subject variability for the reference product is greater than 30%. This is calculated using:

$$CV(\%) = 100\sqrt{e^{s_{WR}^2} - 1}$$

The widening is on a smooth function, i.e. the permitted widening increases as the variability increases (to a maximum of 50%). It is not an all or nothing criteria with 30% being a critical point.

An advantage of Method C is that it directly calculates s_{wr}^2 . However, sometimes the algorithm fails to converge. For that reason the preferred way to get an unbiased estimate of σ_{wr}^2 is using the data from the reference product only.

The following code removes all the test data from the data-set and then fits a model where the residual variance corresponds to the within subject variance for the test product.

```
data var;
set replicate;
if formulation='R';
run;

proc glm data=var;
class subject period sequence;
model logDATA= sequence subject (sequence) period;
run;
```

Results obtained with the different methods for Data Set I and II are summarised in the table below.

Reference within subject CV%

	Model A/B	Model C
Data set I	47.0%	47.3%
Data set II	11.2%	11.5%

The data shows that the variability estimates given by the two approaches are very similar for these examples. There is no dependence on random effects mixed models to estimate within subject variability for a formulation.

4. Discussion

The Guideline on the Investigation of Bioequivalence (CPMP/QWP/EWP/1401/98 Rev. 1) recommends analysing bioequivalence studies using ANOVA and specifying all factors, including subject, as fixed rather than random.

For a 2x2 crossover trial the confidence intervals for the formulation effect will be the same regardless of whether fixed or random effects are used for subject.

For replicate designs the results from the two approaches will differ if there are subjects included in the analysis who do not provide data for all treatment periods. Either approach is considered scientifically acceptable, but for regulatory consistency it is considered desirable to see the same type of analysis across all applications.

For multi-period studies other, more complex statistical models are possible. One of the possibilities is to include a subject by formulation interaction term. Analysis of data currently available shows that the subject by formulation interaction is negligible and therefore models without the interaction effect adequately control the type I error. Thus the same statistical models can be used regardless of the design.

5. Conclusion

The Guideline on the Investigation of Bioequivalence (CPMP/QWP/EWP/1401/98 Rev. 1) recommends analysing bioequivalence studies using ANOVA and specifying all factors, including subjects, as fixed rather than random. The analysis presented above show that this approach (Method A) is feasible even for unbalanced replicate design studies. The advantage of this approach is that it is straightforward and that it appears to be software and software option independent. A simple linear mixed model, which assumes identical within-subject variability (Method B), may be acceptable as long as results obtained with the two methods do not lead to different regulatory decisions. However, in borderline cases and when there are many included subjects who only provide data for a subset of the treatment periods, additional analysis using method A might be required.

For highly-variable drugs it is recommended to estimate the within subject variance using data from the reference formulation only.

ANNEX

Data set I

SUBJECT	DATA	FORMULATION	PERIOD	SEQUENCE	logDATA
1	2285.96	R	1	BABA	7.734541
1	1955.82	T	2	BABA	7.578565
1	1345.94	R	3	BABA	7.204848
1	2856.24	T	4	BABA	7.957261
2	3151.72	T	1	ABAB	8.055704
2	2589.3	R	2	ABAB	7.859143
2	2992.94	T	3	ABAB	8.004011
2	2413.4	R	4	ABAB	7.788792
3	3264.74	T	1	ABAB	8.090935
3	3257.92	R	2	ABAB	8.088844
3	3100.54	T	3	ABAB	8.039332
3	3094.16	R	4	ABAB	8.037272
4	1206.36	T	1	ABAB	7.095363
4	1306.56	R	2	ABAB	7.175153
4	1583.12	T	3	ABAB	7.367153
4	1349.44	R	4	ABAB	7.207445
5	3880.9	R	1	BABA	8.263822
5	7322.88	T	2	BABA	8.898759
5	4429.66	R	3	BABA	8.396078
5	3322.88	T	4	BABA	8.108587
6	978.08	R	1	BABA	6.885591
6	1211.04	T	2	BABA	7.099235
6	973.88	R	3	BABA	6.881288
6	1150.8	T	4	BABA	7.048213
7	2924.06	T	1	ABAB	7.980728
7	2289.98	R	2	ABAB	7.736298
7	2494.28	T	3	ABAB	7.821755
7	3239.14	R	4	ABAB	8.083063
8	2425.46	R	1	BABA	7.793776
8	3705.74	T	2	BABA	8.217638
8	1891.06	R	3	BABA	7.544893
8	8979.12	T	4	BABA	9.102657
9	3825.02	R	1	BABA	8.249319
9	5315.04	T	2	BABA	8.578296
9	5813.16	R	3	BABA	8.667880

9	11475.9	T	4	BABA	9.348004
10	4112.26	R	1	BABA	8.321728
10	3822.86	T	2	BABA	8.248754
10	2459.82	R	3	BABA	7.807843
10	4616.76	T	4	BABA	8.437448
11	3170.3	T	1	ABAB	8.061581
11	2267.1	R	2	ABAB	7.726257
11	1703.32	R	4	ABAB	7.440335
12	2997.18	T	1	ABAB	8.005427
12	2954.78	R	2	ABAB	7.991179
12	5252.66	T	3	ABAB	8.566490
12	3744.54	R	4	ABAB	8.228054
13	2055.7	T	1	ABAB	7.628372
13	983.3	R	2	ABAB	6.890914
13	1771.3	T	3	ABAB	7.479469
13	3293.18	R	4	ABAB	8.099609
14	1590.62	R	1	BABA	7.371879
14	1141.54	T	2	BABA	7.040134
14	1238.34	R	3	BABA	7.121527
14	1285.8	T	4	BABA	7.159136
15	1470.5	T	1	ABAB	7.293358
15	1122.84	R	2	ABAB	7.023616
15	1592.18	T	3	ABAB	7.372859
15	1753.16	R	4	ABAB	7.469175
16	1886.14	R	1	BABA	7.542288
16	2077.28	T	2	BABA	7.638815
16	2197.62	R	3	BABA	7.695130
16	2194.64	T	4	BABA	7.693773
17	629.16	T	1	ABAB	6.444386
17	498.34	R	2	ABAB	6.211283
17	551.74	T	3	ABAB	6.313077
17	382.18	R	4	ABAB	5.945892
18	464.96	R	1	BABA	6.141951
18	2949.84	T	2	BABA	7.989506
18	1205.58	R	3	BABA	7.094716
18	2145.96	T	4	BABA	7.671342
19	1889.26	R	1	BABA	7.543940
19	5837.14	T	2	BABA	8.671996
19	2375.84	R	3	BABA	7.773106
19	1673.46	T	4	BABA	7.422649
20	793.44	T	1	ABAB	6.676378
20	1169.72	R	2	ABAB	7.064520
20	1072.8	R	4	ABAB	6.978027
21	2085.78	R	1	BABA	7.642898
21	2373.2	T	2	BABA	7.771995
21	1557	R	3	BABA	7.350516
21	2135.28	T	4	BABA	7.666353
22	288.06	R	1	BABA	5.663169
22	309.98	T	2	BABA	5.736508
22	324.18	R	3	BABA	5.781299
22	307.58	T	4	BABA	5.728735
23	524.8	T	1	ABAB	6.263017
23	372.84	R	2	ABAB	5.921149
23	518.92	T	3	ABAB	6.251750
23	604.56	R	4	ABAB	6.404501
24	5866.94	T	1	ABAB	8.677088

24	5547.78	T	3	ABAB	8.621153
24	4386.8	R	4	ABAB	8.386355
25	4008.46	T	1	ABAB	8.296162
25	1898.84	R	2	ABAB	7.548998
25	1565.22	T	3	ABAB	7.355782
25	4875.32	R	4	ABAB	8.491941
26	1197.46	T	1	ABAB	7.087958
26	330.82	R	2	ABAB	5.801574
26	1276.16	T	3	ABAB	7.151611
26	394.82	R	4	ABAB	5.978430
27	13823.18	R	1	BABA	9.534102
27	7618.82	T	2	BABA	8.938377
27	9493.34	R	3	BABA	9.158346
27	8928.44	T	4	BABA	9.096997
28	940.86	R	1	BABA	6.846794
28	1188.7	T	2	BABA	7.080616
28	882.02	R	3	BABA	6.782215
28	1226.38	T	4	BABA	7.111822
29	2175.24	R	1	BABA	7.684894
29	2654.36	T	2	BABA	7.883959
29	3235.26	R	3	BABA	8.081865
29	3033.3	T	4	BABA	8.017406
30	1194.9	T	1	ABAB	7.085818
30	826.66	R	2	ABAB	6.717393
30	610.38	T	3	ABAB	6.414082
30	594.14	R	4	ABAB	6.387115
31	4108.68	R	1	BABA	8.320857
31	7399.52	T	2	BABA	8.909170
31	4461.62	T	4	BABA	8.403267
32	792.22	T	1	ABAB	6.674839
32	999.74	R	2	ABAB	6.907495
32	1179.4	T	3	ABAB	7.072761
32	1678.96	R	4	ABAB	7.425930
33	3925.52	R	1	BABA	8.275254
33	3789.74	T	2	BABA	8.240053
33	3463.82	R	3	BABA	8.150127
33	4576.64	T	4	BABA	8.428720
34	1708.58	R	1	BABA	7.443418
34	2500.84	T	2	BABA	7.824382
34	1263.3	R	3	BABA	7.141483
34	2048.42	T	4	BABA	7.624824
35	943.06	T	1	ABAB	6.849130
35	769.22	R	2	ABAB	6.645377
35	848.8	T	3	ABAB	6.743824
35	1193.88	R	4	ABAB	7.084964
36	2540.42	T	1	ABAB	7.840085
36	2091.18	R	2	ABAB	7.645484
36	2583.66	T	3	ABAB	7.856962
36	1993.98	R	4	ABAB	7.597888
37	851.44	T	1	ABAB	6.746929
37	653.88	R	2	ABAB	6.482924
37	2371.3	T	3	ABAB	7.771194
37	1275.38	R	4	ABAB	7.150999
38	6054.76	R	1	BABA	8.708600
38	7322.18	T	2	BABA	8.898663
38	6746.98	R	3	BABA	8.816850

38	7130.7	T	4	BABA	8.872165
39	5825.64	T	1	ABAB	8.670024
39	6462.82	R	2	ABAB	8.773821
39	7400.48	T	3	ABAB	8.909300
39	6196.84	R	4	ABAB	8.731795
40	1690.42	R	1	BABA	7.432732
40	1292.9	T	2	BABA	7.164643
40	1522.4	R	3	BABA	7.328043
40	1066.58	T	4	BABA	6.972213
41	2783.06	R	1	BABA	7.931306
41	1149.08	T	2	BABA	7.046717
41	877.92	R	3	BABA	6.777555
41	572.42	T	4	BABA	6.349873
42	4759.06	T	1	ABAB	8.467805
42	5831.92	R	2	ABAB	8.671102
42	4154.76	R	4	ABAB	8.332010
43	5399.28	T	1	ABAB	8.594021
43	5425.9	R	2	ABAB	8.598939
43	4344.5	T	3	ABAB	8.376666
43	4507.04	R	4	ABAB	8.413396
44	5611.1	T	1	ABAB	8.632502
44	5444.14	R	2	ABAB	8.602295
44	4805.9	T	3	ABAB	8.477600
44	4960.66	R	4	ABAB	8.509294
45	707.68	R	1	BABA	6.561992
45	3681.66	T	2	BABA	8.211119
45	18454.26	R	3	BABA	9.823051
45	1003.46	T	4	BABA	6.911209
46	2400.64	T	1	ABAB	7.783491
46	1420.6	R	2	ABAB	7.258835
46	1146.68	T	3	ABAB	7.044626
46	5005.72	R	4	ABAB	8.518337
47	483.08	R	1	BABA	6.180182
47	1033.3	T	2	BABA	6.940513
47	644.54	R	3	BABA	6.468537
47	675.3	T	4	BABA	6.515157
48	2157.08	R	1	BABA	7.676511
48	3117.36	T	2	BABA	8.044742
48	2816.14	R	3	BABA	7.943122
48	2850.4	T	4	BABA	7.955215
49	14261.54	T	1	ABAB	9.565322
49	26489.56	R	2	ABAB	10.184506
49	23525.66	T	3	ABAB	10.065847
49	21243.76	R	4	ABAB	9.963818
50	1552.24	T	1	ABAB	7.347454
50	1569.32	R	2	ABAB	7.358398
50	2090	T	3	ABAB	7.644919
50	1479.98	R	4	ABAB	7.299784
51	3834.44	R	1	BABA	8.251779
51	4899.76	T	2	BABA	8.496942
51	3702.9	R	3	BABA	8.216872
51	5677.02	T	4	BABA	8.644182
52	5925.92	R	1	BABA	8.687091
52	967.9	T	2	BABA	6.875129
52	797.02	R	3	BABA	6.680880
52	939.38	T	4	BABA	6.845220

53	3528.48	T	1	ABAB	8.168622
53	2037.36	R	2	ABAB	7.619410
53	3211.68	T	3	ABAB	8.074549
53	2906.74	R	4	ABAB	7.974787
54	937.16	R	1	BABA	6.842854
54	6327.96	T	2	BABA	8.752733
54	1054.92	R	3	BABA	6.961220
54	1766.02	T	4	BABA	7.476484
55	3437.98	T	1	ABAB	8.142639
55	3731.8	R	2	ABAB	8.224646
55	4832.72	T	3	ABAB	8.483165
55	3310.24	R	4	ABAB	8.104776
56	1011.14	T	1	ABAB	6.918834
56	654.02	R	2	ABAB	6.483138
56	858.58	T	3	ABAB	6.755280
56	908.12	R	4	ABAB	6.811377
57	1003.34	R	1	BABA	6.911090
57	4739.94	T	2	BABA	8.463780
57	697.84	R	3	BABA	6.547990
57	2504.52	T	4	BABA	7.825852
58	6496.34	R	1	BABA	8.778994
58	5949.36	T	2	BABA	8.691039
58	6003.38	R	3	BABA	8.700078
58	6373.72	T	4	BABA	8.759939
59	1247.58	R	1	BABA	7.128961
59	1116.88	T	2	BABA	7.018294
59	1166.74	R	3	BABA	7.061969
59	2658.38	T	4	BABA	7.885472
60	33929.62	T	1	ABAB	10.432044
60	24943.44	R	2	ABAB	10.124366
60	19110.22	T	3	ABAB	9.857979
60	12805.18	R	4	ABAB	9.457605
62	2280.5	T	1	ABAB	7.732150
62	1714.48	R	2	ABAB	7.446865
62	4034.28	T	3	ABAB	8.302583
62	3420.76	R	4	ABAB	8.137618
63	3376.72	T	1	ABAB	8.124660
63	2242.8	R	2	ABAB	7.715480
63	1719.54	T	3	ABAB	7.449812
63	2342.32	R	4	ABAB	7.758897
64	912.34	R	1	BABA	6.816013
64	2104.42	T	2	BABA	7.651795
64	2061.04	R	3	BABA	7.630966
64	1496.5	T	4	BABA	7.310884
65	3957.94	R	1	BABA	8.283479
65	5895.6	T	2	BABA	8.681962
65	5859.58	R	3	BABA	8.675833
65	5073.48	T	4	BABA	8.531782
66	1165.7	T	1	ABAB	7.061077
66	1248.62	R	2	ABAB	7.129794
66	1168.68	T	3	ABAB	7.063630
66	1300.42	R	4	ABAB	7.170443
67	1197.4	R	1	BABA	7.087908
67	1119.34	T	2	BABA	7.020495
68	1709.72	R	1	BABA	7.444085
68	2532.4	T	2	BABA	7.836923

68	1581.02	R	3	BABA	7.365825
68	2807.4	T	4	BABA	7.940014
69	2798.84	T	1	ABAB	7.936960
69	2454.1	R	2	ABAB	7.805515
69	5334.84	R	4	ABAB	8.582014
70	4318.42	R	1	BABA	8.370645
70	2182.66	T	2	BABA	7.688300
70	1649.16	R	3	BABA	7.408021
70	1620.32	T	4	BABA	7.390379
71	470.24	T	1	ABAB	6.153243
71	208.04	R	2	ABAB	5.337730
72	2098.3	T	1	ABAB	7.648883
72	1919.76	R	2	ABAB	7.559955
72	2817.76	T	3	ABAB	7.943698
72	2041	R	4	ABAB	7.621195
73	6667.32	T	1	ABAB	8.804973
73	5289.84	R	2	ABAB	8.573543
73	7300.28	T	3	ABAB	8.895668
73	9711.84	R	4	ABAB	9.181101
74	2036.76	R	1	BABA	7.619116
74	1948.04	T	2	BABA	7.574579
74	1539.58	R	3	BABA	7.339265
74	2079.14	T	4	BABA	7.639710
75	767.3	T	1	ABAB	6.642878
75	1046.3	R	2	ABAB	6.953015
75	1390.36	T	3	ABAB	7.237318
75	3019.18	R	4	ABAB	8.012741
76	12097.5	T	1	ABAB	9.400754
76	12694.42	R	2	ABAB	9.448918
76	10999.24	T	3	ABAB	9.305581
76	9406.52	R	4	ABAB	9.149158
77	1115.5	R	1	BABA	7.017058
77	1115.3	T	2	BABA	7.016879
77	1111.78	R	3	BABA	7.013718
77	2352.82	T	4	BABA	7.763370
78	20373.54	R	1	BABA	9.921992
78	13689.6	T	2	BABA	9.524392
78	20585.02	R	3	BABA	9.932319
78	24498.14	T	4	BABA	10.106352

Data Set II

SUBJECT	DATA	FORMULATION	PERIOD	SEQUENCE	logDATA
1	4053.6	R	1	2	8.307361
1	3970.4	T	2	2	8.286622
1	3748.8	R	3	2	8.229191
2	2986.2	R	1	2	8.001757
2	2378.8	T	2	2	7.774351
2	2804.6	R	3	2	7.939016
3	3464.4	R	1	3	8.150295
3	3340.2	R	2	3	8.113786
3	4028.8	T	3	3	8.301224
4	4105	T	1	1	8.319961
4	3191.2	R	2	1	8.068152
4	3803.6	R	3	1	8.243703
5	4767.8	T	1	1	8.469640
5	4542.6	R	2	1	8.421255

5	3940	R	3	1	8.278936
6	3050.8	R	1	3	8.023159
6	3027.2	R	2	3	8.015393
6	2419.6	T	3	3	7.791358
7	2530.2	R	1	2	7.836054
7	3072	T	2	2	8.030084
7	2962.6	R	3	2	7.993823
8	2205	T	1	1	7.698483
8	2041.4	R	2	1	7.621391
8	2018	R	3	1	7.609862
9	4647.6	R	1	2	8.444106
9	4159.6	T	2	2	8.333174
9	3400	R	3	2	8.131531
10	2228.2	T	1	1	7.708949
10	2360.4	R	2	1	7.766586
10	2221.2	R	3	1	7.705803
11	1863.8	R	1	3	7.530373
11	2212.4	R	2	3	7.701833
11	2394.4	T	3	3	7.780888
12	2278.4	R	1	3	7.731229
12	3170.4	R	2	3	8.061613
12	3927.2	T	3	3	8.275682
13	2640.4	R	1	3	7.878686
13	2430.4	R	2	3	7.795811
13	2869.2	T	3	3	7.961789
14	3030.8	R	1	2	8.016582
14	2459.8	T	2	2	7.807835
14	2970.4	R	3	2	7.996452
15	2254.4	R	1	2	7.720639
15	1994.8	T	2	2	7.598299
15	2724.4	R	3	2	7.910003
16	2959.6	T	1	1	7.992809
16	3442	R	2	1	8.143808
16	3342.6	R	3	1	8.114504
17	2396.8	T	1	1	7.781890
17	2659.4	R	2	1	7.885856
17	2172	R	3	1	7.683404
18	2725	R	1	3	7.910224
18	2805.6	R	2	3	7.939373
18	3146.6	T	3	3	8.054078
19	2418.8	R	1	2	7.791027
19	2749.8	T	2	2	7.919283
19	2504	R	3	2	7.825645
20	2662.4	R	1	3	7.886983
20	2929.8	R	2	3	7.982689
20	3037.2	T	3	3	8.018691
21	2869.6	R	1	3	7.961928
21	2666.4	R	2	3	7.888485
21	3069	T	3	3	8.029107
22	2949	T	1	1	7.989221
22	2926.8	R	2	1	7.981665
22	2855.4	R	3	1	7.956967
23	3154.8	T	1	1	8.056680
23	3185.6	R	2	1	8.066396
23	3548.6	R	3	1	8.174308
24	1874.8	R	1	2	7.536257

24	1808.8	T	2	2	7.500419
24	2730.8	R	3	2	7.912350

12. Requirements for demonstration of bioequivalence for generics of biphasic modified release formulations for oral use

Biphasic modified release formulations are characterised by two phases of drug release: a first phase determined by the immediate release dose fraction to provide a therapeutic drug level shortly after administration, and a second extended release phase to provide the dose fraction required to maintain an effective therapeutic level for a prolonged period. The clinical rationale behind their development is that a rapid onset of action is required in addition to subsequent prolonged release characteristics.

The principle criteria for the establishment of bioequivalence as stated in the Note for guidance on modified release oral and transdermal dosage forms, Section II (CPMP/EWP/280/96) apply also for multiphasic modified release products. Pharmacokinetic parameters for the establishment of bioequivalence of a generic biphasic modified release formulations with the corresponding innovator formulation need to characterise both phases of drug release to ensure that the plasma concentration – time curves for the generic product correspond to those for the reference product. Therefore, parameters need to establish the equivalence in terms of early drug absorption, reflecting mostly the immediate release component of the product, as well as the equivalence in terms of the second phase reflecting the prolonged release component.

For the pharmacokinetic evaluation, these two phases should be separated through a cut-off time point, which needs to be pre-specified and universally applied to all subjects and for both test product and reference product. The identification of this cut-off time point should aim to describe the plasma concentrations in the first phase driven by the immediate release dose fraction whilst avoiding bias through an increasing contribution of the extended release phase.

Equivalence needs to be shown for both extent and rate of absorption (reflecting AUC and C_{max} for conventional bioequivalence criteria), separately for both phases:

- For the first phase, the assessment of equivalence should be based on the truncated AUC from $t=0$ until the cut-off time describing the immediate release dose fraction, and on C_{max} during the first phase.
- For the second phase, the assessment of equivalence should be based on the AUC from the cut-off time until the end of observation period, and on C_{max} during the second phase.

These considerations are in principle valid for studies in fed state and in fasting state. If no significantly different pharmacokinetic profile between fasting and fed state is expected then the cut-off time point should be identical.

These recommendations are based on the present Note for guidance on modified release oral and transdermal dosage forms, Section II (CPMP/EWP/280/96) and represent the current regulatory thinking. It should be noted that this guideline is currently under revision hence recommendations regarding these aspects may change in the revised guideline.