Enhanced bioavailability and reduced absorption variability of Oral PTH 1-34 in men

Gregory Burshtein1, Jonathan C. Y. Tang2, Hillel Galitzer1, Ariel Rother1, Phillip Schwartz1, William D. Fraser2, Yoseph Caraco3

1Entera Bio Ltd., Israel; 2Bioanalytical Facility, Biomedical Research Centre, Norwich Medical School, Faculty of Medicine and Health Sciences, University of East Anglia, Norwich, UK; 3Hadassah Clinical Research Center, Israel

**RESULTS**

![Figure 1. PK and PD profiles following the administration of original and second modified oral formulation of PTH (1-34) 1.5mg (as base). Pharmacodynamic profile expressed as a change in the levels of albumin adjusted serum calcium. Each data point represents the mean of 9 volunteers.](image1)

The pharmacokinetic (PK) profile of all oral PTH (1-34) formulations is characterized by rapid absorption and elimination rates of the drug. The systemic exposure (AUC) and maximal plasma concentrations (Cmax) following the administration of the modified oral PTH (1-34) formulations (MF-1 and MF-2) were notably higher than AUC and Cmax of original formulation (OF) (Table 1). Cmax and AUC of the MF-2 were statistically significantly higher than Cmax and AUC of the original formulation (p = 0.005 and p < 0.01, respectively). Cmax coefficients of variation (CV%) of the basic oral formulation, modified formulation 1 and modified formulation 2 were 123%, 91% and 67%, respectively (Table 1; Figure 2).

![Figure 2. Maximal PTH (1-34) plasma concentrations and its coefficient of variation (Cmax CV%) following administration of OF, MF-1 and MF-2, fixed dose (1.5 mg) oral formulations of PTH (1-34). Each data point represents the mean of 9 healthy volunteers.](image2)

**CONCLUSIONS**

Modification of the original Entera Bio oral delivery system of PTH (1-34) resulted in significantly greater bioavailability and reduced variability in both the Cmax values and the total drug exposure, AUC. Presented results focused on Cmax which is the most relevant factor for determining biological activation of anabolic pathways and calcium regulation. In the specific case of Entera Bio’s oral PTH (1-34) delivery system, this essential ‘sharp and short’ exposure to the drug is achieved due to the fast absorption of the molecule and its rapid elimination from the body. Similarly, the drug pharmacodynamic effect was also enhanced by the novel oral formulation of PTH (1-34).

Reduced inter-subject Cmax variability, enhanced bioavailability and an increased pharmacodynamic effect achieved by the modification of the dosage form, ensure an improved safety profile of oral PTH (1-34) on the one hand and biologically effective blood concentrations of the drug on the other hand. These together with the expected improvement in compliance significantly enhance the potential of Entera Bio’s oral PTH (1-34) becoming a clinical success.

**BACKGROUND**

The oral absorption of polypeptides, is characterized by high dose-to-dose variability due to their low bioavailability. As a result, maintaining the blood drug levels within the therapeutic window is very challenging. An orally administered PTH may have prodigious advantages in the treatment of bone related disorders due to improved patient compliance and adherence. However, in order for PTH, a drug whose specific PK profile is critical for its physiological activity, to be effective and safe, a consistent and reproducible absorption profile is essential. Entera Bio previously developed and presented an oral formulation of PTH(1-34) that achieved biologically relevant plasma concentrations of the drug similar to those of the commercial SC injection. In anticipation of entering more advanced clinical studies, further development of oral PTH(1-34) formulation was performed focusing on the control of the drug absorption while minimizing its variability. The original source of high variability was revealed through numerous in vitro and preclinical studies resulting in the development of a novel and improved oral PTH (1-34) formulations.

![Table 1. Summary of the main pharmacokinetic and pharmacodynamic parameters found in the current study. Comparison: the maximal PTH (1-34) plasma concentration; Cmax CV% - coefficient of variation among the Cmax levels of different volunteers; AUC - total drug exposure; Serum Calcium increase – change in albumin corrected serum Calcium relatively to the baseline; All the data presented as a mean ± SE.* statistically significant in comparison to the original oral formulation of PTH (1-34) (p ≤ 0.05).](image3)

**STUDY DESIGN**

A Phase I, open label, crossover design pharmacokinetic - pharmacodynamic study was conducted at the Hadassah Clinical Research Center at the Hebrew University – Hadassah Medical Center. Nine healthy male volunteers received Entera Bio’s original oral formulation (OF) and two modified oral formulations (MF-1 and MF-2) at the fixed dose of 1.5 mg PTH (1-34). Blood samples were analyzed externally at the Bioanalytical Facility at the University of East Anglia by validated chemiluminescence based assay on the IDS-ISYS automated analyzer. Levels of serum calcium were measured at the clinical laboratory of the Hadassah hospital.