Advances in Paediatric Medicine Development through Direct Powder Extrusion 3D Printing

Antonio Lopalco
University of Bari Aldo Moro
Department of Pharmacy – Pharmaceutical Sciences

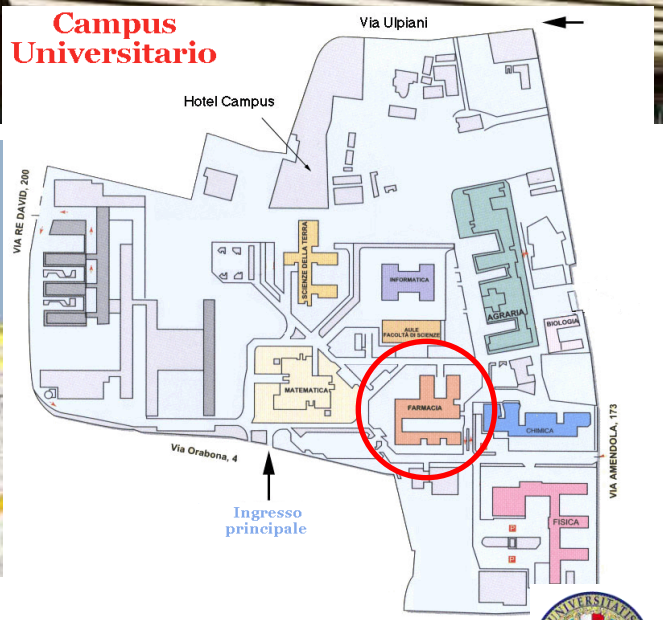
EPTRI Scientific Meeting | 28–29 July 2026 | Warsaw, Poland

THE UNIVERSITY OF BARI ALDO MORO

1925 – The Adriatic University Benito Mussolini was founded

2008 – The University of Bari was named to prof. Aldo Moro

THE DEPARTMENT OF PHARMACY – PHARMACEUTICAL SCIENCES



THE TEAM

Pharmaceutical Technology and Cosmetic Laboratories

Permanent Staff

Nunzio Denora, Angela Lopedota, Massimo Franco, Annalisa Cutrignelli, Valentino Laquintana, Antonio Lopalco, Rosa Maria Iacobazzi

Researchers

Ilaria Arduino, Giuseppe Francesco Racaniello

Post Doc and PhD Students

Vita D'Amico, Milena de Gennaro, Asaam Eljahesh, Mariangela Totaro, Xhoi Xibri, Marina Cortellino, Marzia Rizzello, Francesco Cicinato, Marilisa Pia Riganti, Erica Andriani, Chiaranna Ruta, Martina Zinni, Angelo Angelori

@Phartecolab

@Phartecolab

PHARTECO LAB

Full Prof Nunzio Denora
Brain delivery system - Theranostic NPs
- 3D printing - microfluidic

Associate Prof. Massimo Franco
Ligand for BDZ receptor - Surfactant
- Topical formulation

Associate Prof. Angela Lopedota
Cyclodextrin -
Microparticles - paediatric formulation

Associate Prof. Annalisa Cutrignelli
Liposome -
Amophus Solid dispersion

Associate Prof. Valentino Laquintana
Bioconjugate polymer - Ligand TSPO

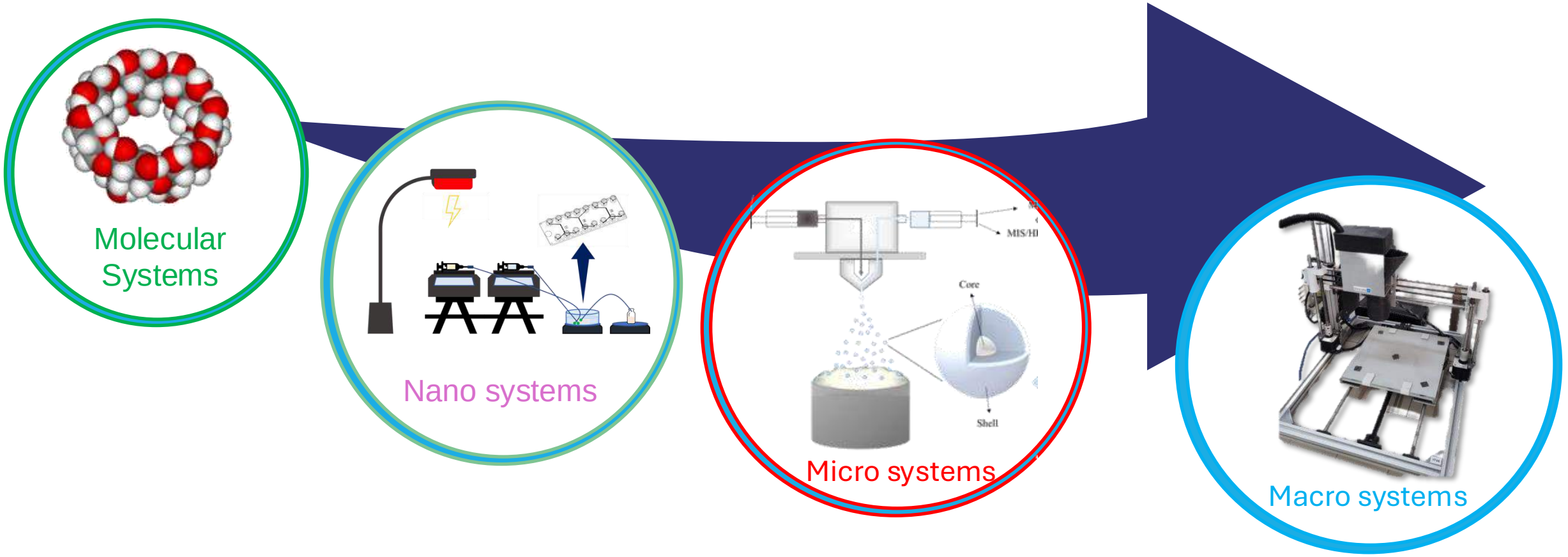
Associate Prof. Antonio Lopalco
Preformulation - 3D printing

Associate Prof. Rosa Maria Iacobazzi
Dendrimers - biohybrid NPs

Researcher Dr. Ilaria Arduino
Solid lipid NPs - Microfluidic

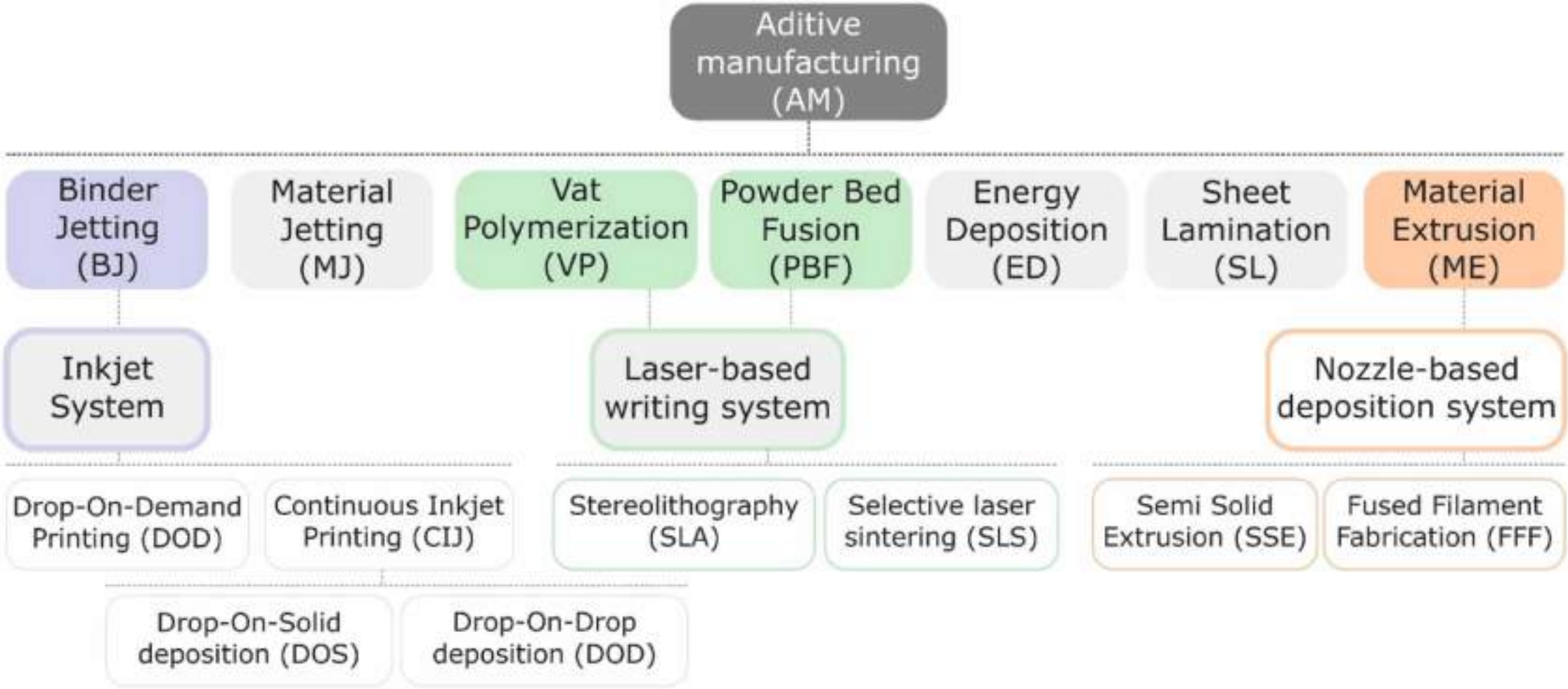
Researcher Dr. Giuseppe Racaniello
Mucodhesive polymers - 3D printing

PLATFORMS



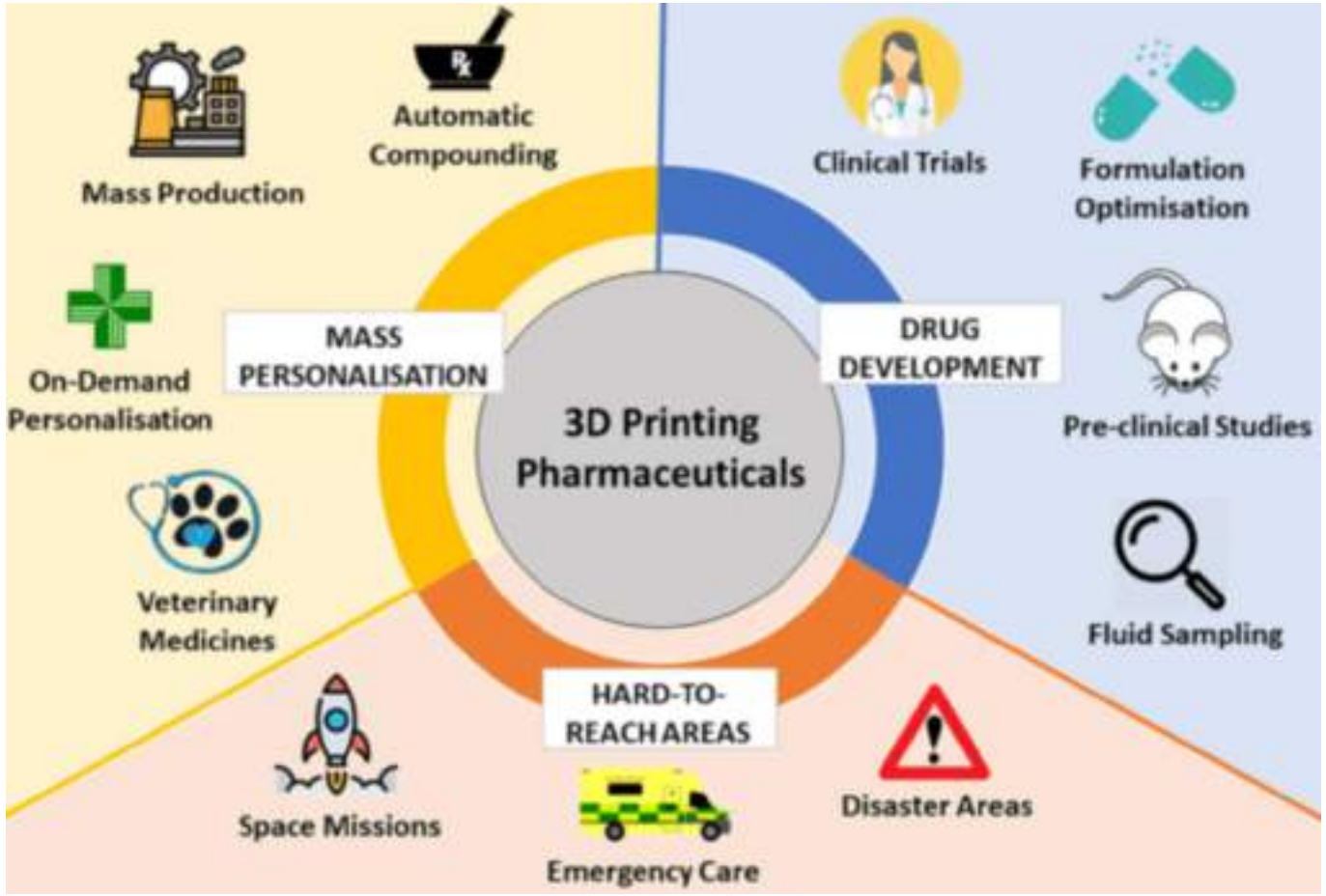
Lab-made and scalable platforms to produce tailored products with features that meet the specific requirements for the patients:
microfluidics, prilling/vibration technology-spray drying, 3D printing

ASTM CLASSIFICATION

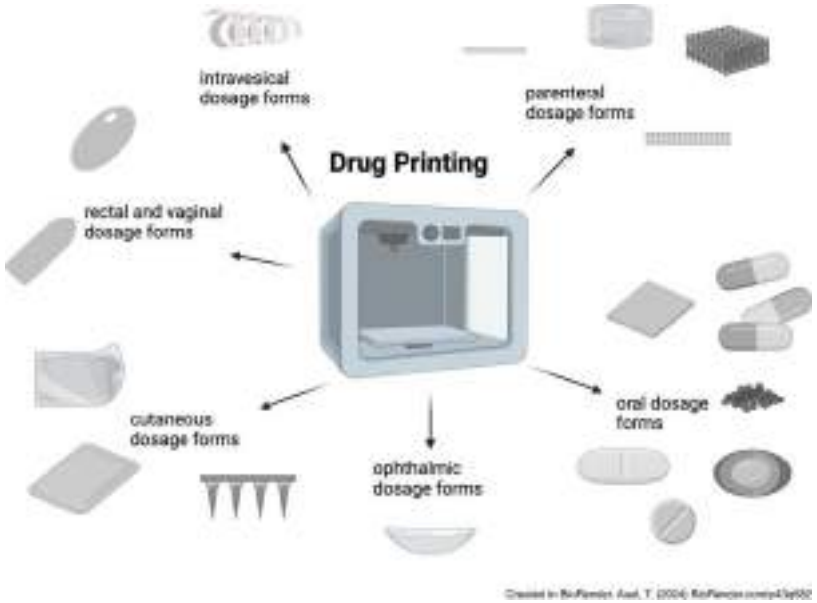


ATSM - American Society for Testing and Materials

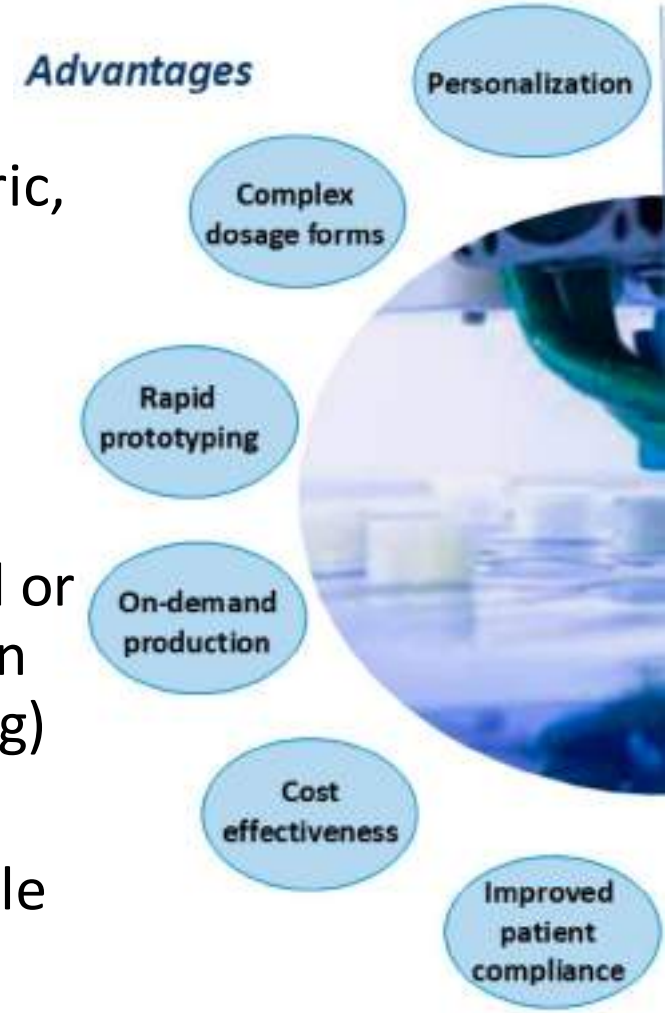
3D PRINTING EMERGING PHARMACEUTICAL APPLICATIONS



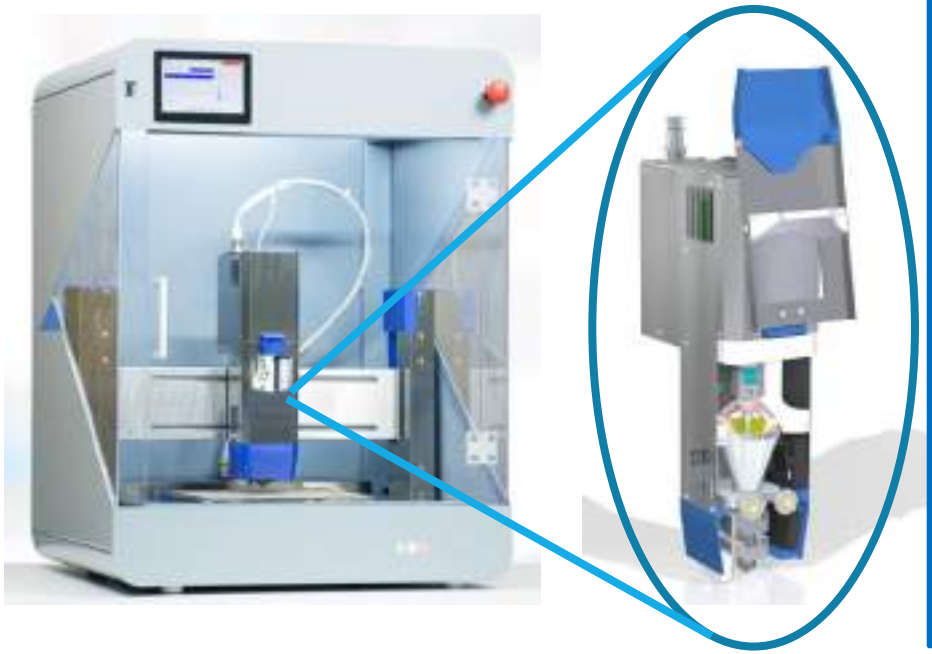
ADVANTAGES

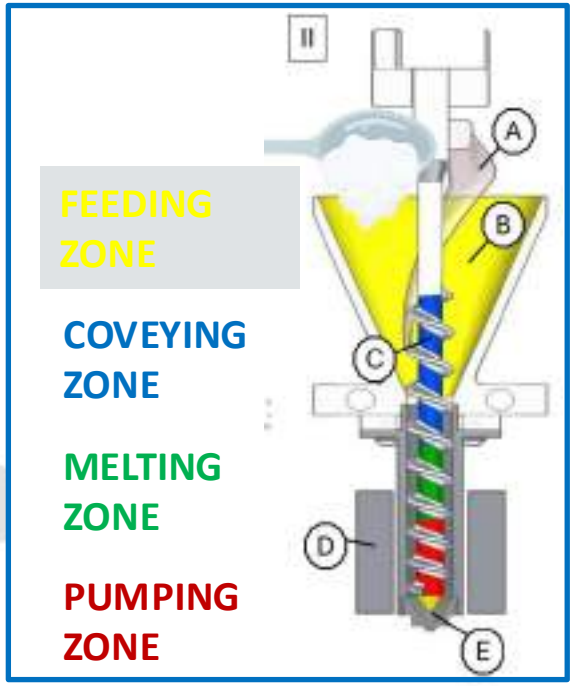


- **Dose individualisation** for paediatric, geriatric, or special patient groups
- **Development of complex dosage forms**, including multilayer or controlled-release systems
- **On-demand production** in hospital or community pharmacies (integration into extemporaneous compounding)
- **Creation of orodispersible dosage forms (ODTs, ODFs)** and implantable devices



DIRECT POWDER EXTRUSION 3D PRINTING TECHNIQUE





Combining the **hot melt extrusion (HME)** process with the **3D printing** technique to generate from pharmaceutical grade powders or pellets customizable solid dosage forms

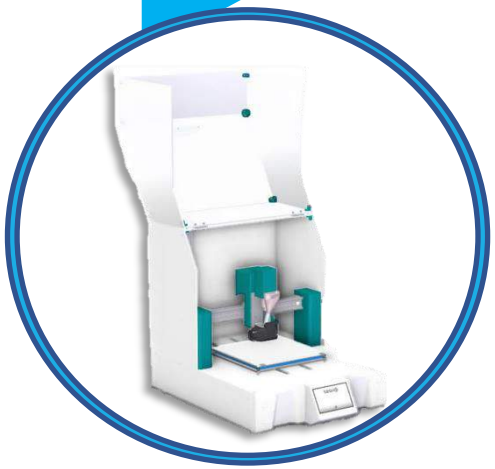
Direct Powder Extruder (DPE)

- Extrude material directly from pellets or powders using a single-screw extruder
- Preparation of the filament by Hot Melt Extrusion (HME) is not necessary
- Continuous, single step production process

DEVELOPMENT STAGES OF THE NEW 3DFORME®

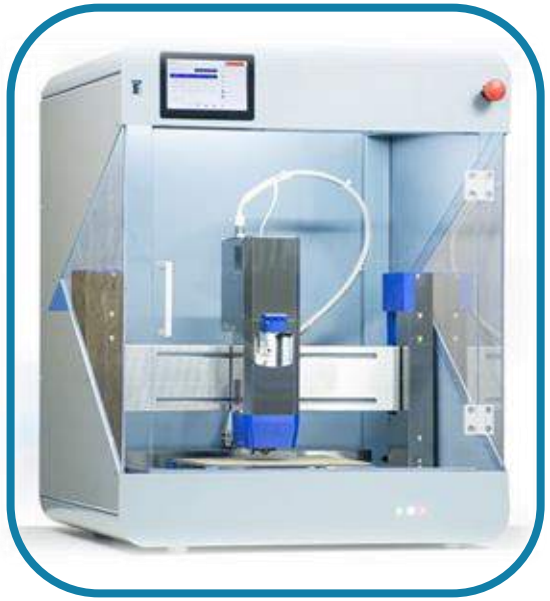
2019

2021



2022

3DFormMe®



2023

FARMALABOR
Farmacisti Associati

PATENTED

EPTRI
EUROPEAN PAEDIATRIC TRANSLATIONAL RESEARCH INFRASTRUCTURE

THE CHILDREN'S MEMORIAL HEALTH INSTITUTE

UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO

CASE STUDIES

BUDESONIDE MINI-TABLETS

MIDAZOLAM ORO-DISPERSABLE FILMS

OLAPARIB TABLETS

BUDESONIDE TABLETS AND EOSINOPHILIC COLITIS

The purpose of this study was to combine direct powder extrusion (DPE) 3D printing and fluid bed coating techniques to create a BUDESONIDE loaded solid oral formulations for the treatment of eosinophilic colitis (EC) paediatric patients


International Journal of Pharmaceutics 632 (2023) 122592

Contents lists available at ScienceDirect

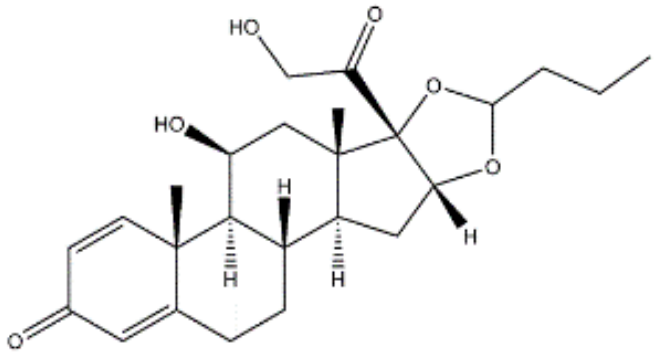
International Journal of Pharmaceutics

journal homepage: www.elsevier.com/locate/ijpharm

Direct cyclodextrin based powder extrusion 3D printing of budesonide loaded mini-tablets for the treatment of eosinophilic colitis in paediatric patients

Monica Pistone [a], Giuseppe Francesco Racaniello [a], Rosanna Rizzi [b], Rosa Maria Iacobazzi [a], Ilaria Arduino [a], Antonio Lopalco [a], Angela Assunta Lopedota [a,*], Nunzio Denora [a,*]

[a] Department of Pharmacy – Pharmaceutical Sciences, University of Bari Aldo Moro, Orabona St. 4, 70125 Bari, Italy
[b] Institute of Crystallography-CNR, Amendola St. 122/o, 70126 Bari, Italy

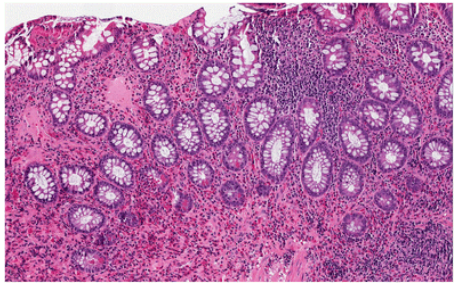


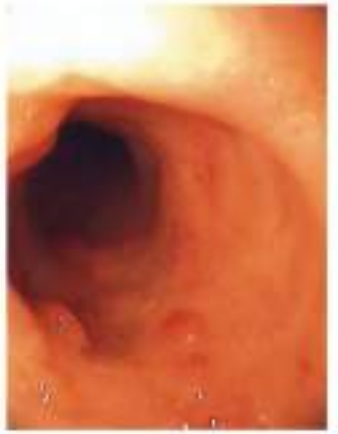
EOSINOPHILIC COLITIS

Rare Disease characterized by elevated colonic infiltration of eosinophils

Clinical scenario associated with this condition appears to be closely related to the layer of the affected intestine leading to abdominal pain, diarrhea, hematochezia, and bloating

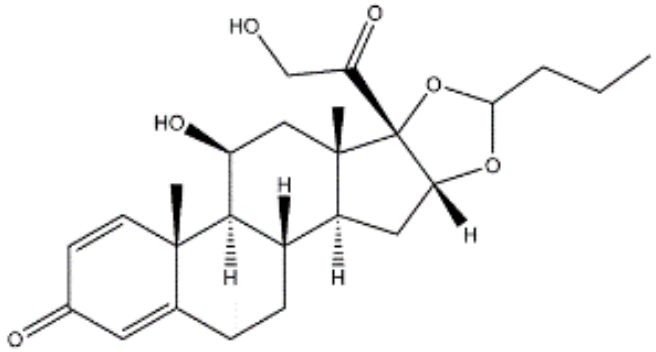
Eosinophilic disorders in the colon can involve patients of all age groups, although a high incidence in the paediatric population has been observed





BUDESONIDE

- ✓ Budesonide (BD), a potent second-generation glucocorticoid with local anti-inflammatory action and reduced systemic side effects
- ✓ BD is used for the local treatment of rare paediatric diseases such as the Eosinophilic Esophagitis (EoE) and the **Eosinophilic Colitis** (EC)
- ✓ BD is BCS Class II drug (low solubility in water, good permeability)



MINI TABLETS CHARACTERIZATION

Table 1
Composition relative to 100 g of powder mixtures for printing.

	BD*	AB*	IC*	HP-β-CD*	PEG 6000*	HPMC*
	% w/w					
MixBD	0.59	20.00	/	/	3.97	75.44
MixBD-CD	0.59	8.17	/	46.41	2.99	41.84
MixIC	/	8.17	47.00**	/	2.99	41.84

* BD = budesonide; AB = Adjuvant Blend consisting of citric acid/tartaric acid/sodium bicarbonate; IC = BD/HP-β-CD inclusion complex; HP-β-CD = hydroxypropyl-β-cyclodextrin; PEG 6000 = polyethylene glycol 6000; HPMC = hydroxypropyl methylcellulose.
** The value corresponds to 0.59% w/w of BD.

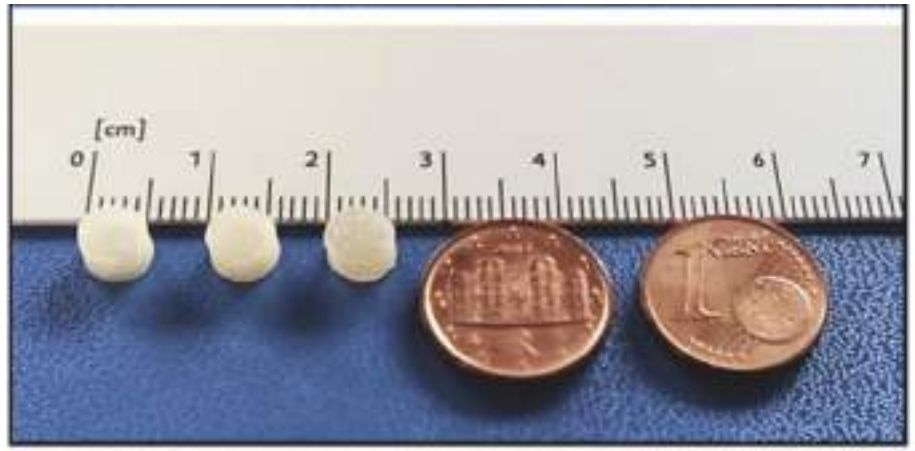


Fig. 2. From left to right: formulation 1 (MT1), formulation 2 (MT2), and formulation 3 (MT3) derived from the direct extrusion of MixBD, MixBD-CD, and MixIC, respectively.

Table 3
For each formulation, the characteristics of each MT obtained by DPE.

MT	Weight Uniformity* (mg)	Drug content* (mg)	Friability* (%)	Breaking Force (N)*	Dimensions (mm)*	
					Diameter	Height
1	128.08 ± 20.17	0.71 ± 0.09	0.022	> 484.00	5.17 ± 0.29	4.14 ± 0.33
2	127.08 ± 10.68	0.68 ± 0.09	0.064	298.67 ± 62.14	5.52 ± 0.21	3.78 ± 0.13
3	130.40 ± 18.39	0.60 ± 0.05	0.038	320.08 ± 97.70	5.46 ± 0.18	3.76 ± 0.21

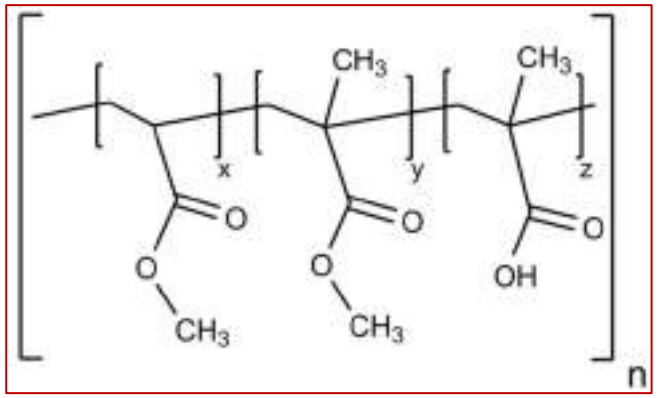
* The value is the average of 10 tablets. ± is the deviation standard.

COATED MINI TABLETS

Angelini Pharma

Table 2
Composition of the polymer mixture used as film coating.

Function	Ingredient	%w/w	Dry substance (g)
Polymer	Eudragit® FS 30 D	43.01	12.9
Plasticizer	Triethyl citrate	0.65	0.65
Anti-tacking	Talc	6.45	6.45
Diluent	Purified water	49.89	
Total		100.0	20.0



selective release at a pH > 7.0

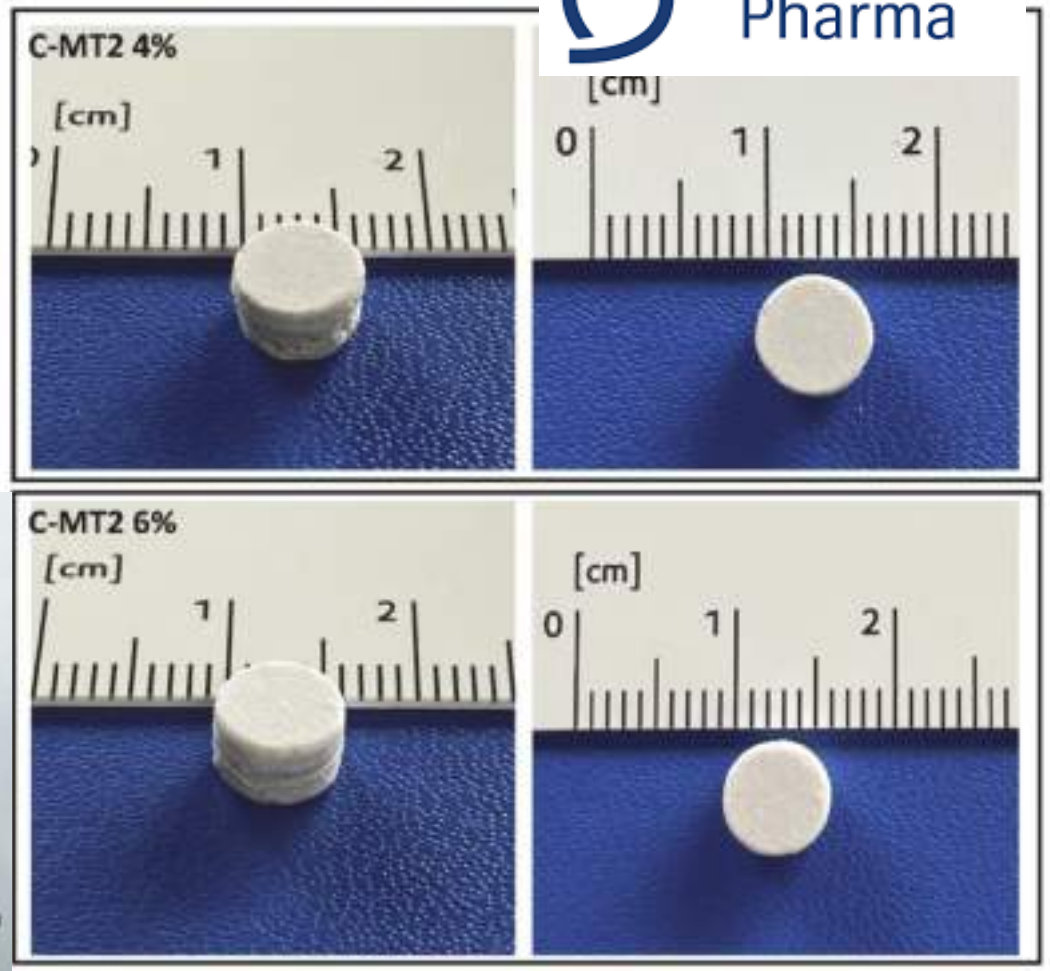


Fig. 8. Images of the C-MT2s formulations at 4 % and 6 % coating.

IN VITRO RELEASE STUDY

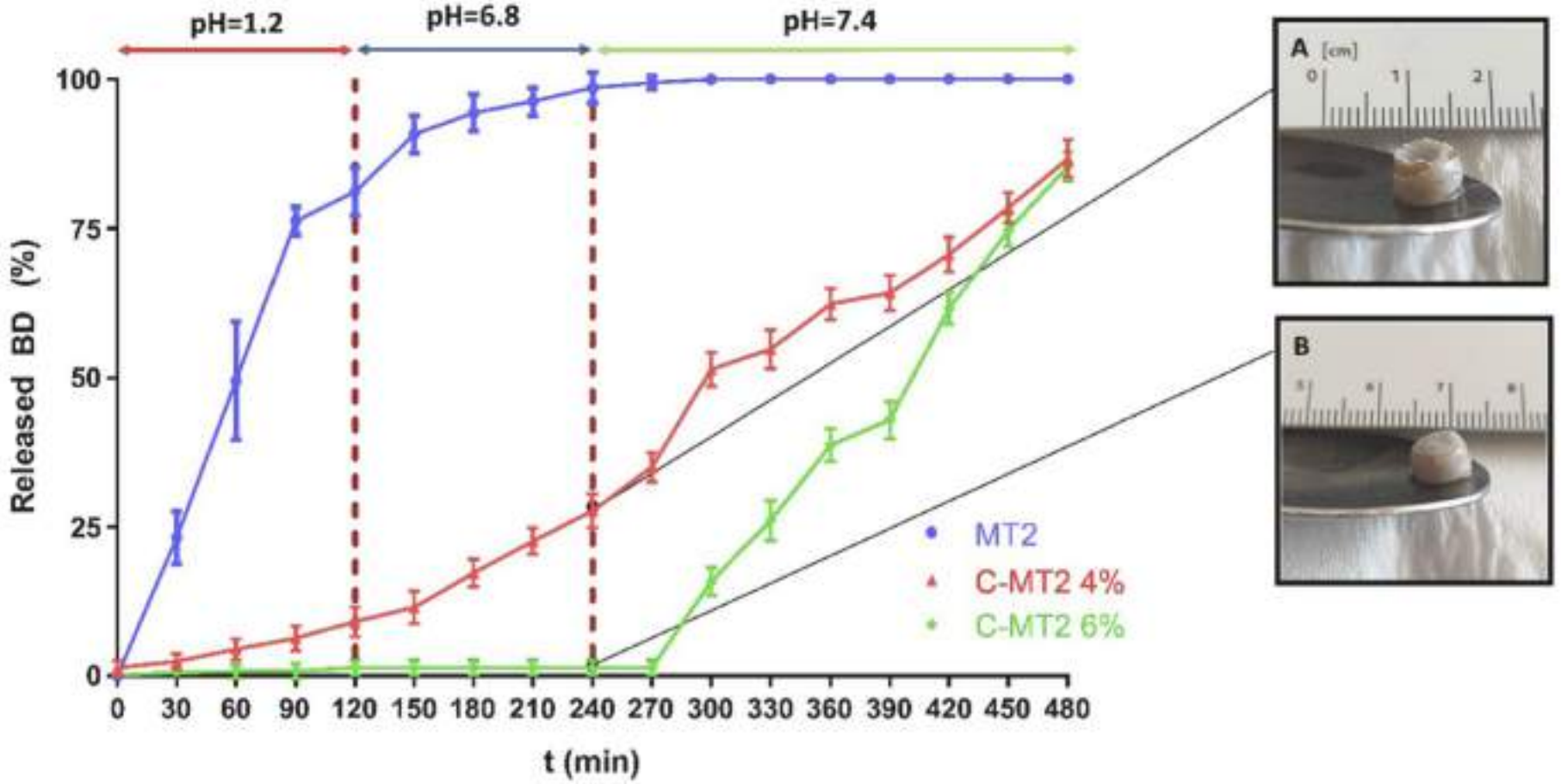


Fig. 11. Release studies of the coated formulations (C-MT2 4 % and C-MT2 6 %) compared with the uncoated MT2 formulation. In the insets A and B, the two C-MT2s are shown after passage in simulated gastric and enteric medium (pH 1.2 and 6.8, respectively).

MIDAZOLAM/γ-CYCLODEXTRIN ORO-DISPERSIBLE FILMS

UNIVERSITÉ de Picardie Jules Verne

Carbohydrate Polymers

journal homepage:

Development of midazolam/γ-cyclodextrin orodispersible films using direct powder extrusion 3D printing: A novel approach to inclusion complex and drug delivery systems formulation[a]

G.F. Racaniello[1], D. Mathiron[2], S. Rigaud[2], N. Denora[1], F. Leonetti[1], A. Lopalco[1,*], F. Djedaini-Pilard[2,*], A.A. Lopedota[1]

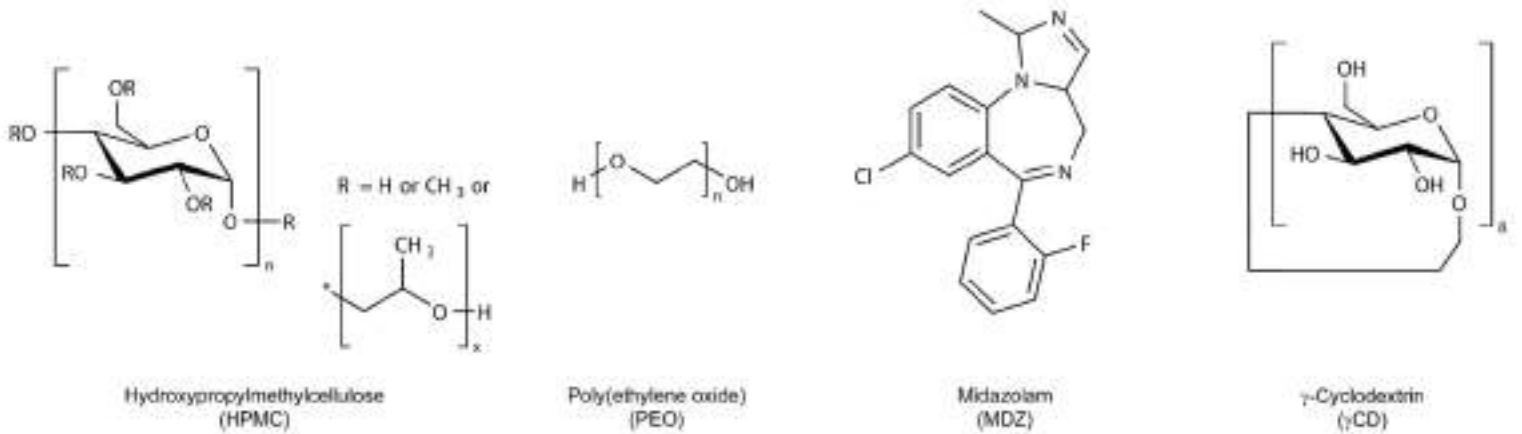


Fig. 1. Polymers hydroxypropyl methylcellulose (HPMC) poly(ethylene oxide) (PEO), γ-cyclodextrin (γCD) and Midazolam (MDZ) chemical structures.

Table 1
Composition of powder blends.

Raw samples			Final powder blends				
Code Raw samples	MDZ:γCD (molar ratio)	MDZ mg (%)	γCD mg (%)	Preformed IC mg (%)	PEO mg (%)	HPMC mg (%)	Code formulations
$M0_{blend}$	1:0	50 (1)	–	–	4975 (98.5)	25 (0.5)	M0
$M1:1_{blend}$	1:1	50 (1)	200 (4)	–	4725 (94.5)	25 (0.5)	M1:1
$IC1:1_{blend}$	1:1	–	–	250 (5)[a]	4725 (94.5)	25 (0.5)	IC1:1
$CD1_{blend}$	0:1	–	200 (4)	–	4775 (95.5)	25 (0.5)	CD1

[a] Equivalent to 50 mg of MDZ.

PAEDIATRIC AND EMERGENCY CARE APPLICATIONS

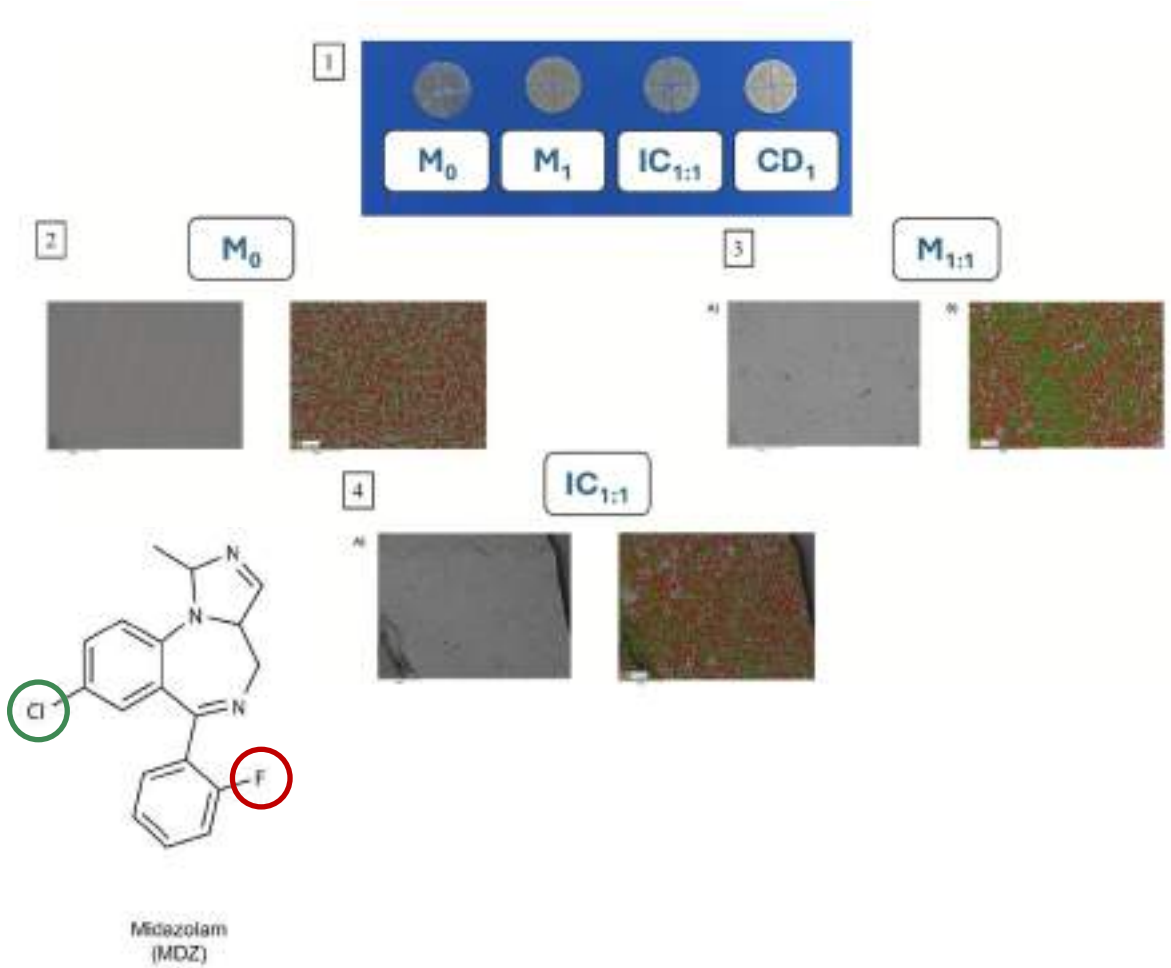
ePTRI European Paediatric Translational Research Infrastructure

THE CHILDREN'S MEMORIAL HEALTH INSTITUTE

ODFs CHARACTERIZATION

Table 3
Average MDZ weight (g) and dimensions (mm) in the different printed ODFs and their standard deviations (S.D.). Number of replicates (n) = 5 for each formulation.

Printed films	Weight ± S. D. (g)	Diameter ± S. D. (mm)	Thickness ± S. D. (mm)	Drug loading (%)
M0	0.050 ± 0.004	14.96 ± 0.16	0.67 ± 0.05	0.95 ± 0.03
M1:1	0.049 ± 0.005	15.12 ± 0.22	0.71 ± 0.06	0.96 ± 0.04
IC1:1	0.050 ± 0.004	15.26 ± 0.24	0.69 ± 0.04	0.94 ± 0.06
CD1	0.052 ± 0.007	14.88 ± 0.14	0.72 ± 0.06	/



DISINTEGRATION AND DISSOLUTION TIME EVALUATION

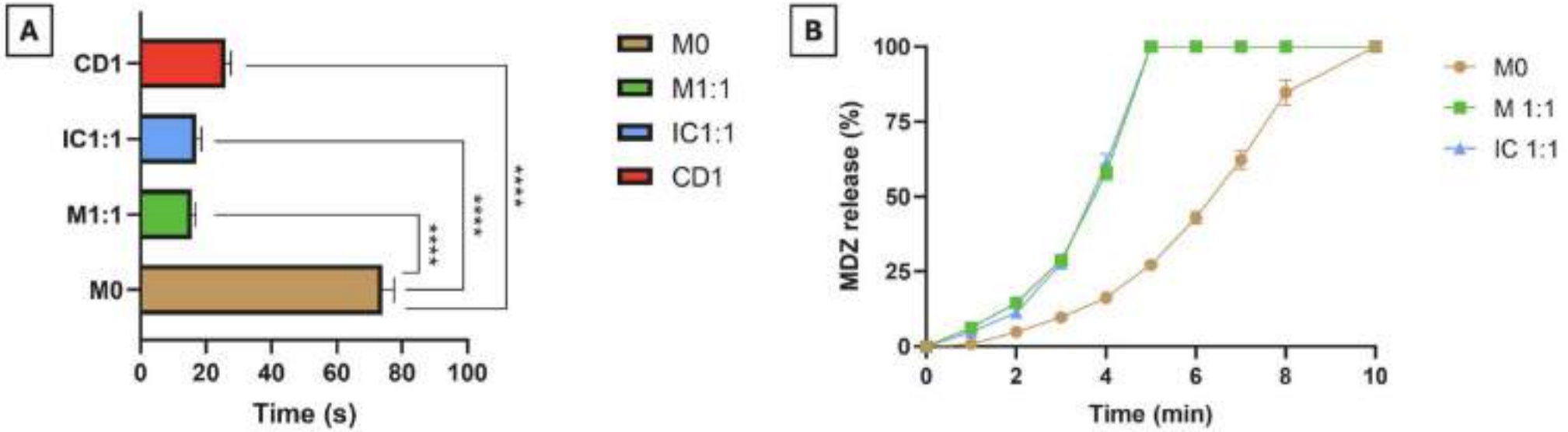
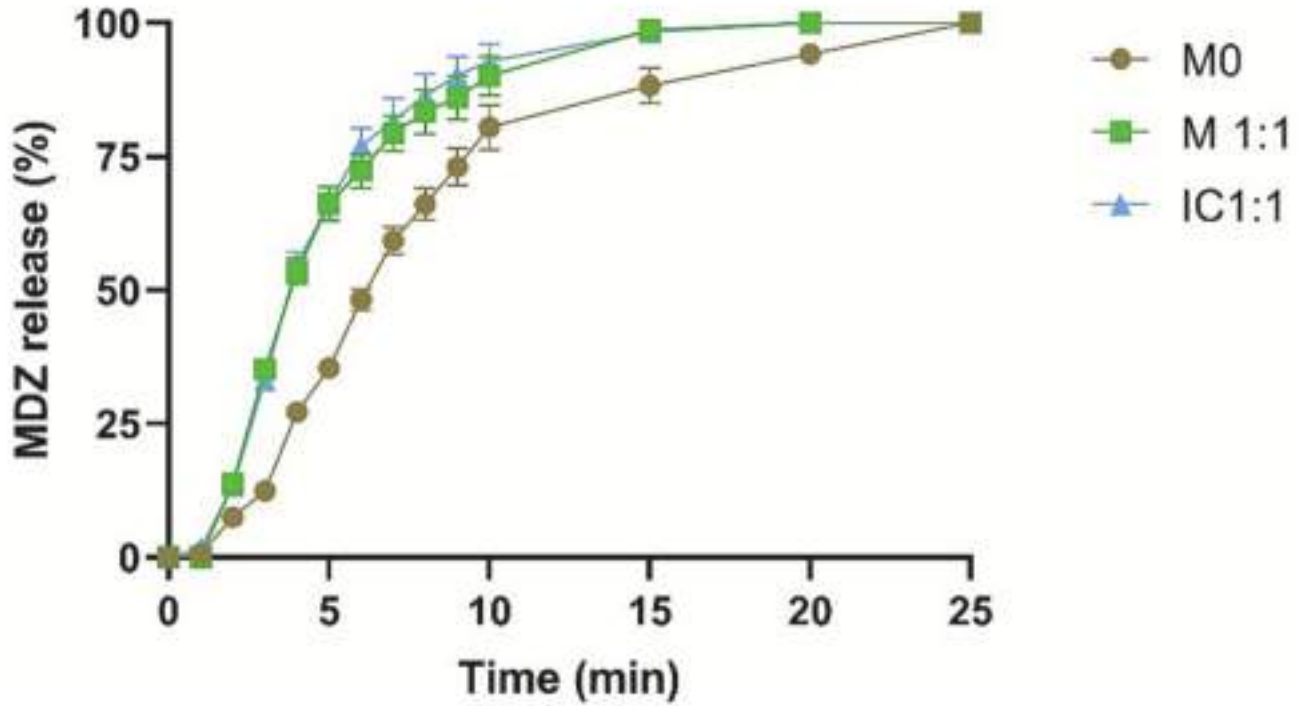


Fig. 9. Total disintegration time (A) and dissolution profile (B) of the ODFs. Error bars shown in figure represent the SD. $n = 5$ ODFs. **** (p value <0.0001).

EX-VIVO MUCOADHESION AND DISSOLUTION TEST



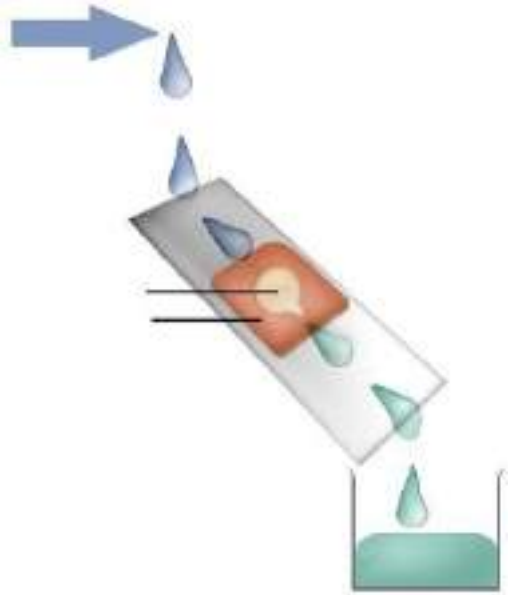
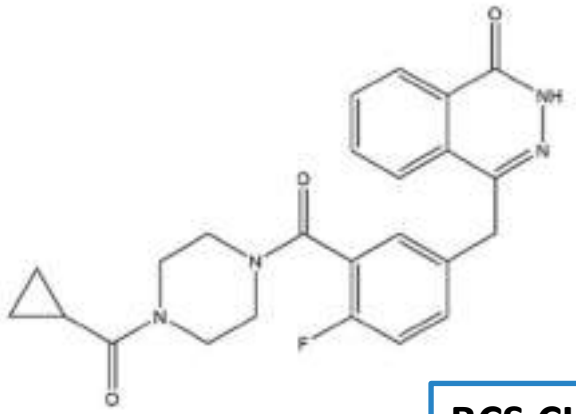


Fig. 10. The drug release profile from the formulation set on the porcine tissue. Error bars shown in figure represent the SD. $n = 5$ ODFs.

OLAPARIB: BACKGROUND AND AIM

UNPUBLISHED DATA



OLAPARIB

BCS CLASS IV

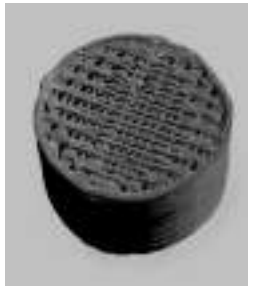
POLIMORPHS A and L

ANTICANCER PARP INHIBITOR

POLIMORPH FORM A

AMORPHOUS FORM

DPE 3D PRINTING



Personalization dosage

Control drug solid state

Modulate drug release

CONCLUSIONS

The case studies presented demonstrate that the Direct Powder Extrusion 3D Printing technique has significant potential for the personalized manufacturing of pediatric dosage forms

By enabling flexible, on-demand production tailored to individual patient needs, this technology represents a promising step toward the routine implementation of personalized pediatric medicines

THANK YOU FOR YOUR ATTENTION