جامعة السلطان مولاي سليمان
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Université Sultan Moulay Slimane

CED-SP
Faculté Polydisciplinaire
Béni-Mellal

# Faculté Polydisciplinaire de Béni Mellal
# Centre d'Études Doctorales « Sciences Pluridisciplinaires »

## Avis de soutenance d'une thèse de doctorat

Le Doyen de la Faculté Polydisciplinaire de Béni-Mellal porte à la connaissance du public que **Mme Chaymaa HACHIMI ALAOUI** soutiendra une thèse de doctorat intitulée : **Mise au point de biomatériaux encres à base d'hydrogels composites pour la régénération osseuse.**

La soutenance publique aura lieu **le Lundi 14 septembre 2026 à 10H, Salle 01 du Pôle d'Etudes Doctorales**, devant le jury composé de :

| | | | |
|---|---|---|---|
| Président / Rapporteur | Anass BELBACHIR | PES | Université Cadi Ayyad, Maroc |
| Rapporteur | Olivia KEROUREDAN | MCH | Université de Bordeaux, France |
| Rapporteur | Soumya ELABED | PES | Université Sidi Mohamed Ben Abdellah, Maroc |
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| Examinateur | Mustapha RAIHANE | PES | Université Cadi Ayyad, Maroc |
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# Fiche d'informations sur la thèse

- **Nom de la doctorante :** Chaymaa HACHIMI ALAOUI
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  - Licence Science et Techniques en Techniques d'Analyses et Contrôle Qualité, Faculté des Sciences et Techniques, Béni Mellal.
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- **Co-directeur de thèse**: Pr. Gildas RETHORE (INSERM UMRS 1229 RMeS – Nantes Université, Nantes, France).
- **Lieu de réalisation du travail:** INSERM UMRS 1229 RMeS – Nantes Université, Nantes, France
- **Cadre de financement:** Projet bilatéral Franco-Marocain et Partenariat Hubert Curien (PHC) TOUBKAL (Toubkal/23/175 – Campus France : 48607YF).
- **Période de thèse :** 2021-2022 → 2025-2026.

# Articles publiés

1) **Hachimi Alaoui, C.;** Maitre, P.; Pare, A.; Charbonnier, B.; Gauthier, O.; Weiss, P.; Corre, P.; Fatimi, A.; Rethore, G. Impression 3D et règènèration osseuse oro-faciale. L'Information Dentaire 2026, 16, 68-74.

2) **Hachimi Alaoui, C.;** Weiss, P.; Fatimi, A.; Réthore, G. A Brief Overview on Polysaccharide-Based Hydrogels in 3D Bioprinting for Biomedical Applications: Cases of Cellulose, Chitosan, and Lignin. Engineering Proceedings 2024, 81, 21. https://doi.org/10.3390/engproc2024081021.

3) Saadan, R.; **Hachimi Alaoui, C.;** Quraishi, K.S.; Afridi, F.; Chigr, M.; Fatimi, A. Recent Progress in Hydrogel-Based Bioinks for 3D Bioprinting: A Patent Landscape Analysis and Technology Updates. Journal of Research Updates in Polymer Science 2024, 13, 130-146. https://doi.org/10.6000/1929-5995.2024.13.14.

4) **Hachimi Alaoui, C.;** Rethore, G.; Weiss, P.; Fatimi, A. Sustainable Biomass LigninBased Hydrogels: A Review on Properties, Formulation, and Biomedical Applications. International Journal of Molecular Sciences 2023, 24, 13493. https://doi.org/10.3390/ijms241713493.

5) **Hachimi Alaoui, C**.; Fatimi, A. A 20-year patent review and innovation trends on hydrogel-based coatings used for medical device biofabrication. Journal of Biomaterials Science, Polymer Edition 2023, 34, 1255-1273. https://doi.org/10.1080/09205063.2022.2161777.

6) Saadan, R.; **Hachimi Alaoui, C**.; Ihammi, A.; Chigr, M.; Fatimi, A. A Brief Overview of Lignin Extraction and Isolation Processes: From Lignocellulosic Biomass to Added-Value Biomaterials. Environmental and Earth Sciences Proceedings 2024, 31, 3. https://doi.org/10.3390/eesp2024031003.

7) **Hachimi Alaoui, C**.; Fatimi, A. A preparation method of softwood lignin derivatives: US9347177B2 patent evaluation. Environmental Sciences Proceedings 2022, 22, 20. https://doi.org/10.3390/IECF2022-13069.

8) **Hachimi Alaoui, C.;** Fatimi, A. The international patent classification: Case of hydrogels. MOL2NET'22 Proceedings 2022. https://doi.org/10.3390/mol2net-08- 12452.

# ABSTRACT

The repair of oro-facial bone critical-sized defects remains a major clinical challenge. Current therapeutic strategies-based on allografts as the gold standard, present significant limitations including restricted tissue availability and limited integration with the host tissue. Consequently, the development of personalized scaffolds has become a major focus in biomedical research. In this context, three-dimensional printing has emerged as a promising technology for the fabrication of patient-specific implants matching the morphology of the defects, with controlled porosity, pore interconnectivity, and tunable mechanical properties enabling vascularization, cell adhesion, bioactive molecule delivery, subsequently osteogenesis.

The use of biopolymer-based hydrogels as inks has enabled the development of biomimetic matrices that closely resemble the native extracellular matrix due to their biocompatibility, high water content, and ability to encapsulate and control the release of bioactive molecules. Furthermore, the incorporation of a mineral phase into the hydrogel matrix, particularly biphasic calcium phosphate (BCP), allows the fabrication of osteoconductive biomaterials with enhanced mechanical properties, while also promoting cell adhesion and proliferation. In addition, the incorporation of growth factors, especially Bone Morphogenetic Protein-2 (BMP-2), enhances osteoblastic differentiation and activates molecular pathways involved in osteogenesis. Moreover, integrating BMP-2 into 3D-printed hydrogel composites offers a promising altealternative to collagen sponges currently used in clinical practice, overcoming several of their limitations.

The aim of this thesis is to develop 3D-printed osteoconductive biomaterials with osteoinductive potential to promote oro-facial bone defects regeneration.

**Key words:** Bone regeneration; 3D printing; Hydrogels; Biocomposites, BMP-2.