nature portfolio

Corresponding author(s): Nadine NASSIF

Last updated by author(s): Sep 20, 2024

Reporting Summary

Nature Portfolio wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Portfolio policies, see our Editorial Policies and the Editorial Policy Checklist.

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a	Confirmed	
☐	☒	The exact sample size (*n*) for each experimental group/condition, given as a discrete number and unit of measurement
☐	☒	A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
☐	☒	The statistical test(s) used AND whether they are one- or two-sided *Only common tests should be described solely by name; describe more complex techniques in the Methods section.*
☒	☐	A description of all covariates tested
☒	☐	A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons
☐	☒	A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)
☐	☒	For null hypothesis testing, the test statistic (e.g. *F*, *t*, *r*) with confidence intervals, effect sizes, degrees of freedom and *P* value noted *Give P values as exact values whenever suitable.*
☒	☐	For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
☒	☐	For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
☒	☐	Estimates of effect sizes (e.g. Cohen's *d*, Pearson's *r*), indicating how they were calculated

Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	DataViewer V2 (Optics 11) Faxitron SR v1.5
Data analysis	MATLAB (release R2018B) software for mechanical characterization analysis NDP.view2.8.24 for ewe histological viewing RadiAnt DICOM Viewer 2022.1.1 Excel v16.89.1 for basic statistics and plotting ImageJ v1.52a software (Fiji, Tokyo, Japan) was used to analyse radiographic images from the rat experiment as well as scans and radio images (Faxitron) from the first ewe experiment in order to estimate the percentage of bone filling ImageJ2 v2.0.0 software (Fiji, Tokyo, Japan) for ewe (n°2 experiment) histomorphometric analysis WAXD data was integrated radially using FIT2D version 18 (beta) software NRecon Skyscan Software 1.7.1.6. (Bruker) for 3D reconstruction

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio guidelines for submitting code & software for further information.

Data

Policy information about availability of data

All manuscripts must include a data availability statement. This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our policy

All data generated or analysed during this study are included in the manuscript (and the supplementary information files) or available upon request to the corresponding author (apply to raw imaging data for all samples).

Research involving human participants, their data, or biological material

Policy information about studies with human participants or human data. See also policy information about sex, gender (identity/presentation), and sexual orientation and race, ethnicity and racism.

Reporting on sex and gender	N/A
Reporting on race, ethnicity, or other socially relevant groupings	N/A
Population characteristics	N/A
Recruitment	N/A
Ethics oversight	N/A

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☒ Life sciences ☐ Behavioural & social sciences ☐ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

Life sciences study design

All studies must disclose on these points even when the disclosure is negative.

Sample size	Rat experiment (n=10 for implant group, n= 8 for negative control group): The initial sample size was not predetermined using statistical methods but is based on previous similar work (Vigier et al. 2011) and on the maximum number of available animals regarding ethical matters, ensuring that each group (negative control, Col40 and Col100) is sufficiently represented. Considering the variability of the in vivo response, the sample size should be the maximum possible. However, considering ethical concerns, the number of animals was limited to the minimum sample size required to address the study's hypothesis. Hence, a sample size of 10 is likely to obtain tendencies between the implant group while a sample size of 8 for the negative control group (critical size defect) is sufficient as the critical size character is well-documented for 8 mm defect in rat. For ewe studies: Considering the animal used (ewe) and taking into account ethical matters, the number of animals had to be reduced to the minimum acceptable number. Thanks to the model used (Nuss et al. 2006), several implantation sites were available on each animal (a maximum of 8 by animal), allowing for a sample size of n=5 to n=12 for the groups in the two ewe experiments.
Data exclusions	Rat experiment: Animals were excluded if (i) they died during the course of the study or (ii) the surgical procedure was not performed properly (leading to inconsistent or biased bone reconstruction). Three (3) animals were excluded from the analysis. In the negative control group, one animal died during the procedure and another had an incomplete defect created during the surgcial procedure leading to an abnormal full defect reconstruction (critical size defects do not spontaneously heal). In the Col100 group, one rat had its underlying dura mater and mid-sagittal sinus severly damaged resulting in a defectuous bone reconstruction. Ewe experiments: no data were excluded. As explained in the manuscript, only the most inner part of the defect was analyzed in histology to avoid the strong and non-specific surface reaction due to the mechanical load applied on the external part.
Replication	Reproducibility was ensured by the selected sample size and by the use of well-known bone defect models, producing consistent results.
Randomization	Animals were randomly assigned to experimental groups without selection. All animals were similar in terms of species, outbreed, age and average weight.

Blinding	Rat experiment: blinding was applied for the bone percentage analysis on microradiographies. However, full blinding was not reallistic due to the presence of critical-size defect negative control (no reconstruction), and no blinding was used for the histological analysis as this analysis is more qualitative and necessarily implies several layers of material selection. N°1 ewe experiment: blinding was applied for the determination of the percentage of bone reconstruction based on scanner and radiographic images. However, full blinding was not reallistic due to the presence of critical-size defect negative control (no reconstruction), and no blinding was applied for the histological analysis. N°2 ewe experiment: blinding was applied for the comparative anatomopathological analysis (histological analysis).

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☒	☐ Palaeontology and archaeology
☐	☒ Animals and other organisms
☒	☐ Clinical data
☒	☐ Dual use research of concern
☒	☐ Plants

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging

Animals and other research organisms

Policy information about studies involving animals; ARRIVE guidelines recommended for reporting animal research, and Sex and Gender in Research

Laboratory animals	Two-year-old healthy French ewes (bone was extracted from the proximal part of the diaphysis and distal epiphysis of humerus and femur) 8-week-old male Wistar rats (bone was extracted from the center of calvaria)
Wild animals	The study did not involve wild animals
Reporting on sex	The findings do not apply only to one sex
Field-collected samples	The study did not involve samples collected from the field
Ethics oversight	Studies with ewes were reviewed and approved by the IMM Recherche's Institutional Animal Care and Use committee (IACUC) prior to the initiation of this study. The Animal Care and Use Committee of IMMR is registered at the CNREEA under the Ethics Committee n°37. The animal research center (IMM-Recherche) received an agreement (n°75-14-01) by the "Direction Départementale de la Protection des Populations". The studies were also performed in compliance with the Principles of Laboratory Animal Care, formulated by the National Society for Medical Research, and the Guide for the Care and Use of Laboratory Animals, by the Institute of Laboratory Animal Resources (published by the National Academy Press, Washington, D.C, 1996), as amended by the Animal Welfare Act of 1970 (P.L 91-579) and the 1976 amendments to the Animal Welfare were followed. The study with rats was reviewed and approved by the Animal Care Committee of the University Paris Descartes (No. P2.JLS.174.10).

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Plants

Seed stocks	*Report on the source of all seed stocks or other plant material used. If applicable, state the seed stock centre and catalogue number. If plant specimens were collected from the field, describe the collection location, date and sampling procedures.*
Novel plant genotypes	*Describe the methods by which all novel plant genotypes were produced. This includes those generated by transgenic approaches, gene editing, chemical/radiation-based mutagenesis and hybridization. For transgenic lines, describe the transformation method, the number of independent lines analyzed and the generation upon which experiments were performed. For gene-edited lines, describe the editor used, the endogenous sequence targeted for editing, the targeting guide RNA sequence (if applicable) and how the editor was applied.*
Authentication	*Describe any authentication procedures for each seed stock used or novel genotype generated. Describe any experiments used to assess the effect of a mutation and, where applicable, how potential secondary effects (e.g. second site T-DNA insertions, mosiacism, off-target gene editing) were examined.*