nature portfolio

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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	No custom algorithm or software was used in this study.
Data analysis	No custom algorithm or software was used in this study.

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

The data that support the findings of this study are provided in the Source Data file, Supplementary Data 1, and are also available from the corresponding author upon request. The coordinates of the optimized structures are provided as source data.

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	For in vitro study, the sample size of each group was not less than 3. For animal experiments, the sample size of each group was 5.
Data exclusions	No data were excluded from the analyses.
Replication	Each in vitro and animal experiment consisted of three biological replicates.
Randomization	In vitro and animal experiment did not involve randomization.
Blinding	In vitro and animal experiment did not involve blinding.

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

Eukaryotic cell lines

Policy information about [cell lines and Sex and Gender in Research]()

Cell line source(s)	Human dental pulp stem cells (DPSCs) were provided by Shanghai YSRIBIO industrial CO., LTD. Human oral keratinocytes (HOKs) were provided by Shanghai Engineering Research Center of Tooth Restoration and Regeneration.

Authentication	The cell lines used were not authenticated.
Mycoplasma contamination	The cell lines were not tested for mycoplasma contamination
Commonly misidentified lines (See ICLAC register)	The above two of cells (DPSCs and HOKs) can not be found commonly misidentified lines in ICLAC.

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	8 weeks old of Sprague-Dawley (SD) rats were used. All experimental rats were housed in standard Specific Pathogen-Free level animal facilities, ensuring optimal environmental control. The animal facility maintained a light/dark cycle of 12 h light and 12 h dark to simulate natural circadian rhythms. Each cage contained up to two rats to ensure comfort and reduce aggressive behavior due to overcrowding. Rats had free access to water and food. For surgical interventions, experimental rats were anesthetized with 2% pentobarbital sodium to ensure that the rats experienced no pain throughout the process. Subsequently, the rats were placed in a recovery room at 26 oC and closely monitored until they were fully awake. For collecting the samples of treated enamel blocks, all rats were euthanized by carbon dioxide inhalation, ensuring a painless process. Then the enamel blocks were removed from mouths of rats, flushed by deionized water, and dried at room temperature to assess the remineralization effect.
Wild animals	This study did not involve wild animals.
Reporting on sex	We presume that the sex of the animal has little effect on the results. 15 female SD rats were used in animal experiments.
Field-collected samples	The study did not involve samples collected from the field.
Ethics oversight	The Ethical Committee of Shanghai Ninth People's Hospital.

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

Plants

Seed stocks	No plant was used in this study.
Novel plant genotypes	No plant was used in this study.
Authentication	No plant was used in this study.