Supplementary

Deep learning framework structure and mechano-regulatory method workflow.
Figure S1 shows the workflow of mechano-regulatory method. The loop went through 35 times for each case of dental implant, to obtain 35-days bone healing history. The part of FEM calculation was colored in yellow. The part of classifier of tissue phenotype was colored in Blue. Note that the range of the value of cell stimulus factor S corresponding to the five tissue phenotypes were listed in Table S1. Figure S2 shows the workflow of the current deep learning framework for comparisons.
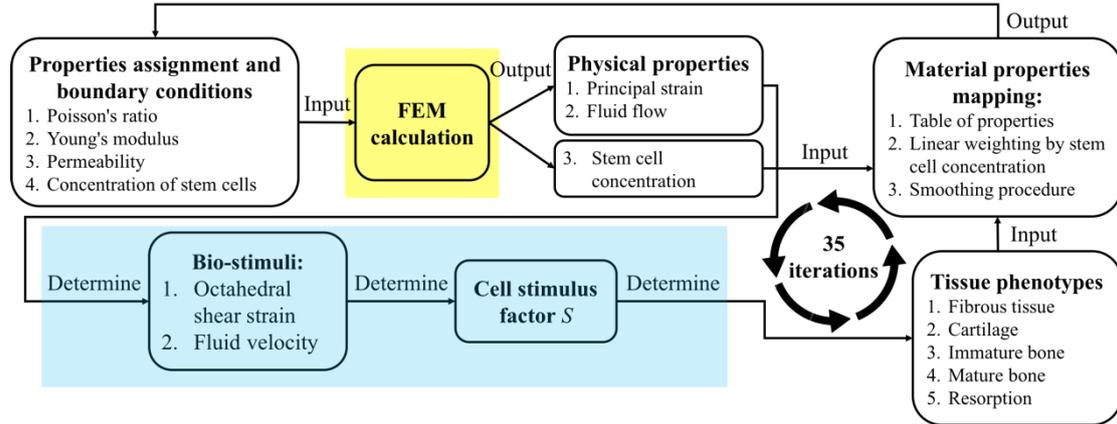

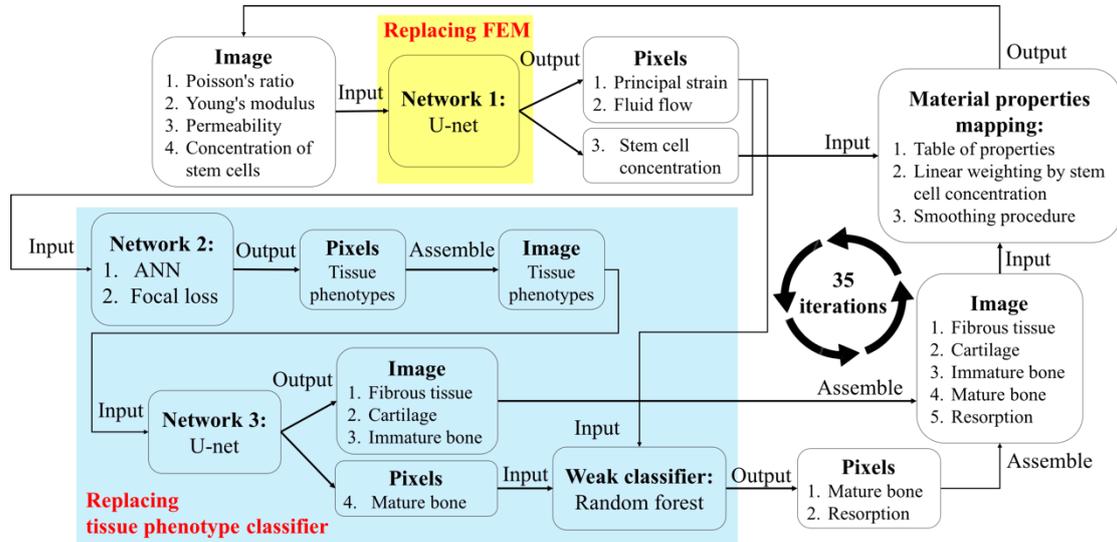Fig. S1 The workflow of mechano-regulatory method.

Fig. S2 The current DL framework structure.

Table S1 The ranges of cell stimulus factor for different tissue phenotypes.

S			Tissue phenotype
$3<$	S		Fibrous tissue
$1<$	S	≤ 3	Cartilage
$0.266<$	S	≤ 1	Immature bone
$0.010<$	S	≤ 0.266	Mature bone
	S	≤ 0.010	Initial resorption

Finite element model setting. The geometry of the dental implant model and the applied boundary conditions in FEM calculation are shown in Fig. S3 a. The model is two-dimensional axisymmetric about the y axis. A downward displacement of 8um along the y axis corresponding to a biting force of 100N was applied on the top of the implant. The node at the bottom-left was fixed, while the remaining nodes at the bottom were constrained in the y axis. The material properties of Ti-6Al-4V dental implants, tissue phenotypes, and bones used in the current FEM calculation are listed in Table S2. The dashed line in Fig. S3 a indicates cell origin which is defined as the source of stem cell migration. The area marked by the yellow rectangle in Fig. S3 a is the region as input data for machine learning. It was meshed by 210×52 elements allowing a direct transformation into pixels. An enlarged image as input data are shown in Fig. S3 b.

Bone-implant contact (BIC), bone area (BA) and marginal bone loss (MBL) were used in the current study to evaluating the performance of dental implants. MBL is defined as the percentage of the total area of resorption elements in the region of interest (ROI). ROI for MBL is the total area above the first thread (illustrated as shaded area) in Fig. S3 c. BIC is defined as the percentage of the total length of the interface between the implant elements and the mature/immature bone elements in ROI of BIC. Where the ROI of BIC is the total length of all the threads in the implant. ROI of BIC in one of the threads is illustrated with a red solid line in Fig. S3 d. Similarly, BA is the percentage of the total area of the mature/immature bone elements in the ROI of BA. ROI of BA is the total area between all the threads (illustrated as shaded area) in Fig. S3 d.

Table S2 Material properties of the tissues used in the current model.

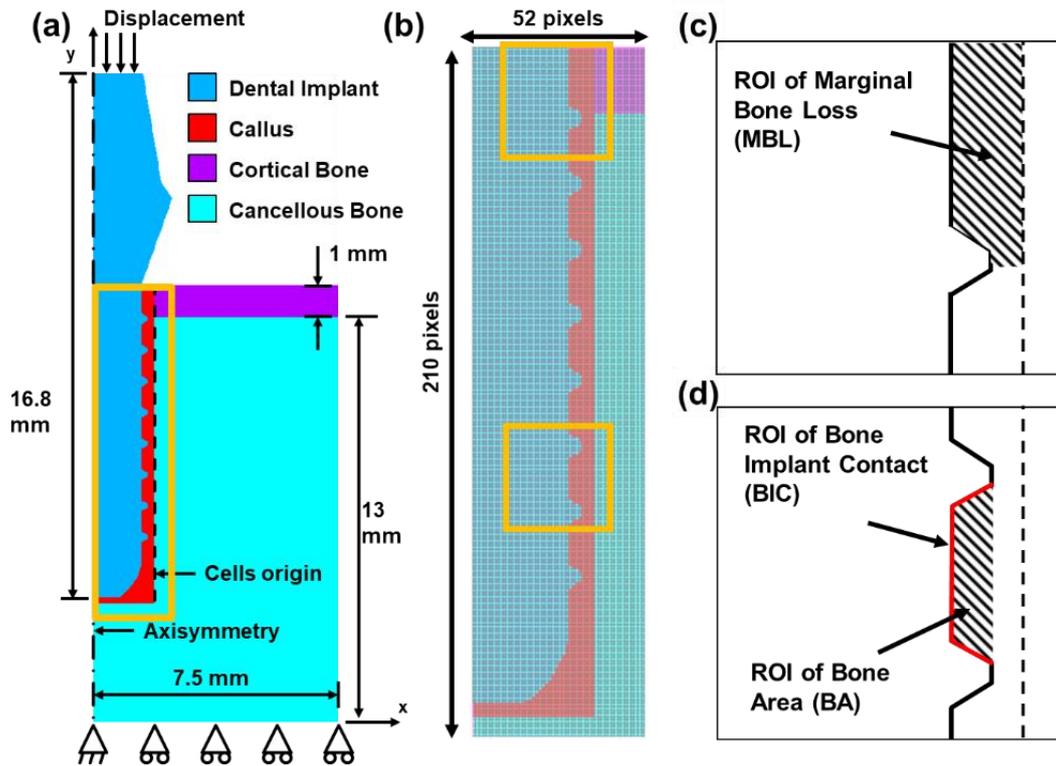|	Young's modulus (MPa)	Poisson's ratio	Permeability (m^4/Ns)
Granulation tissue	1	0.17	10^{-14}
Fibrous tissue	2	0.17	10^{-14}
Cartilage	10	0.17	5×10^{-15}
Immature bone	1000	0.30	10^{-13}
Mature bone	6000	0.30	3.7×10^{-13}
Cortical bone	20000	0.30	10^{-17}
Cancellous bone	6000	0.30	3.7×10^{-13}
Ti-6Al-4V	113000	0.30	N/A

Fig. S3 (a) The illustration of the FEM model for dental implant and bones. (b) The region marked by the yellow rectangle in (a), which is a typical input image data for machine learning. (c) ROI of MBL. (d) ROI of BIC and BA in one thread.

The distribution of the accuracy of the predicted tissue phenotypes. Fig. S4 shows a histogram plot of the accuracy of the predicted tissue phenotypes on the 35th day in the cell-differentiation regions, i.e. the red region shown in Fig. S3 a, of all the 65 cases of dental implant. It is remarkable that, even after a complete healing period (i.e. 35 days/iterations), the mean accuracy 88% was achieved.
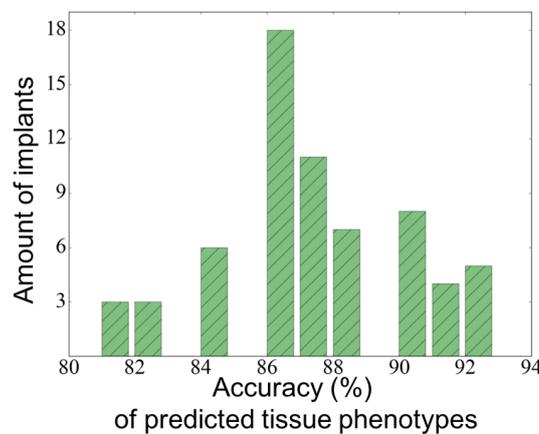

Fig. S4 The histogram plot of the accuracy of the predicted tissue phenotypes on the 35th day in the cell-differentiation regions of all the 65 cases of dental implant.