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BONE REMODELLING DUE TO DENTAL PROSTHESIS

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ABSTRACT

One important effect of dental restoration, specifically with implants, is that it changes the normal biomechanical response patterns within the supporting bones. As a result, the bone will engage in a process of biological remodelling, where the alveolar bone is self-adapted to new functional environment. Bone-remodelling can lead to a certain abutment movement, bone density changes, tissue ingrowth into implants or formation of infrabony (sub-gingival) pockets in the surrounding alveolar bone. Such a process may in turn influence the long-term success of the restoration in either a negative or a positive manner. On the one hand, the prosthetic component or abutment tooth will not remain well-supported if its bone bed gradually disappears due to unsuitable or abnormal stress-strain patterns. On the other hand, the adaptive course may strengthen the bone/prosthesis composite as a whole if a positive remodelling can be stimulated. Further, orthodontic, maxillofacial or restorative surgical planning would be greatly served if such adaptive changes could be predicted and controlled even in an approximate manner. Thus, this study devotes to develop suitable computational remodeling algorithms for predicting bone density changes with different scenarios of dental prostheses.

In order to determine the relationship between Young's modulus and bone density in this paper, the mathematical relationship have been established literature as summaried in Table 1 below.

Table 1 Relationhsip between bone density and Young's modulus

Dental cancellous bone		Dental cortical bone	
Mesio-distal	$E_1 = 2349\rho_a^{2.15}$	Superior-inferior	$E_1 = -23.93 + 24\rho$
Bucco-lingual	$E_2 = 1274\rho_a^{2.12}$	Circumferential	$E_2 = -13.05 + 13\rho$
Infero-superior	$E_3 = 194\rho_a^{1}$	Radial	$E_2 = 0.279 + 6.12\rho$

Mathematically, remodelling-induced density variation can be expressed as a differential equation in terms of stimulus error (signal) $\psi(t) - \overline{\psi}(t)$, as

$$d\rho(t,\boldsymbol{x})/dt = C[\psi(t,\boldsymbol{x}) - \overline{\psi}] \quad (1)$$

where C is the internal remodelling constant, $\psi(t,\boldsymbol{x})$ is a time and site dependent mechanical stimulus and $\overline{\psi}$ is the corresponding reference stimulus. Experimental measurements showed that there is a lazy zone where bone growth and resorption are in

equilibrium and the mechanical stimulus does not lead to apparent density change. Thus, the remodelling algorithm Eq. (1) can be revised as,

$$d\rho(t,\boldsymbol{x})/dt = C[\psi(t,\boldsymbol{x}) - \overline{\psi}(1+\delta)] \quad \text{if } \psi(t,\boldsymbol{x}) > \overline{\psi}(1+\delta) \tag{2a}$$

$$d\rho(t,\boldsymbol{x})/dt = C[\psi(t,\boldsymbol{x}) - \overline{\psi}(1-\delta)] \quad \text{if } \psi(t,\boldsymbol{x}) < \overline{\psi}(1-\delta) \tag{2b}$$

$$d\rho(t,\boldsymbol{x})/dt = 0 \quad \text{if } \overline{\psi}(1-\delta) \le \psi(t,\boldsymbol{x}) \le \overline{\psi}(1+\delta) \tag{2c}$$

where δ=10% is adopted in this paper to define the lazy zone according to [3].

Tables 2 and 3 present the 2D bone remodelling results in the buccal-lingual and mesial-distal sections respectively, where the strain energy density is adopted as mechanical stimulus ψ. It is observed that at month 6, the bone density distribution is rather uniform, where remodelling is almost non-visible in the cortical area. However, an indication that slight remodelling is taking place in the cancellous bone, especially in the peri-implant region where small signs of remodelling activity can be seen. However, when comparing the density contours in month 18 with month 24 in both the cases, large similarity is clearly visible, indicating that the bone remodelling process is reaching its stable stage. The results appears logic from clinical perspective, which indicates the effectiveness of the remodelling algorithms.

Table 2 Bone remodelling process (buccal-lingual section)

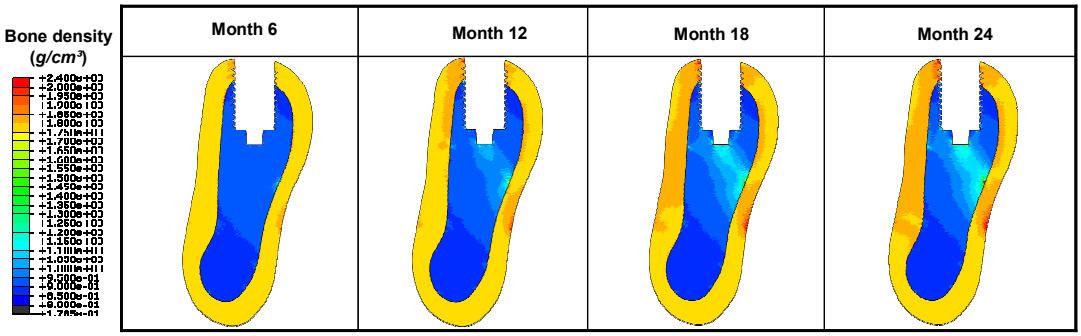
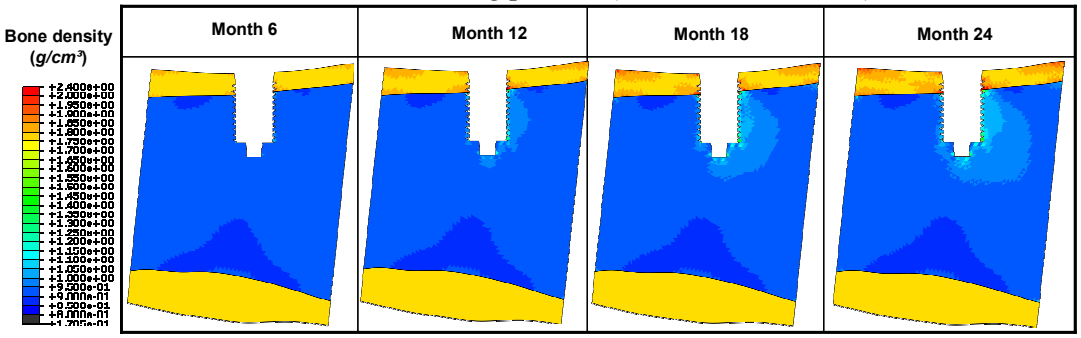


Table 3 Bone remodelling process (mesial-distal section)



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