THE FAILURE ENVELOPE CONCEPT AND STRESS SHIELDING IN THE BONE-DENTAL IMPLANT SYSTEM

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Abstract

Dental implants interact with the jawbone through their common interface. While the implant is an inert structure, the jawbone is a living one that reacts to mechanical stimuli. Setting aside mechanical failure considerations of the implant, the bone is the main component to be addressed. With most failure criteria being expressed in terms of stress or strain values, their fulfillment can mean structural flow or fracture. However, in addition to those effects, the bony structure is likely to react biologically to the applied loads by dissolution or remodeling, so that additional (strain-based) criteria must be taken into account.

While the literature abounds in studies of *particular* loading configurations, e.g. angle and value of the applied load to the implant, a *general* study of the admissible implant loads is still missing.

We present the concept of **failure envelopes** for the dental implant-jawbone system, thereby defining admissible combinations of vertical and lateral loads for various failure criteria of the jawbone. Those envelopes are compared in terms of conservatism, thereby providing a systematic comparison of the various failure criteria and their determination of the admissible loads.

Stress shielding considerations suggest that the dental implant material's compliance should be matched to that of the host bone. However, this belief has not been confirmed from a general perspective, either clinically or numerically.

The idea is to characterize the influence of the implant stiffness on its functionality using the above-mentioned failure envelope approach.

We performed numerical simulations to generate failure envelopes for all possible loading configurations of dental implants, with stiffness ranging from very low (polymer) to extremely high, through that of bone, titanium and ceramics.

The analyses show that, irrespective of the failure criterion, stiffer implants allow for improved implant functionality. The latter reduces with increasing compliance, while the trabecular bone

experiences higher strains, albeit of an overall small level. Micromotions remain quite small irrespective of the implant’s stiffness.

Consequently, the current paradigm favoring reduced implant material’s stiffness out of concern for stress or strain shielding, or even excessive micromotions, is not supported by the present calculations, that point exactly to the opposite.