EDITORIAL

Are Oral Implants Stronger Than Natural Teeth?

A friend recently asked me, "Are oral implants stronger than natural teeth?" Initially, I thought the question didn't make sense; it seemed to be a case of comparing apples to oranges. But after thinking about it, I decided it was a good question, since trying to answer it brings up almost every major topic in the biomechanics of teeth, implants, and bridgework. Here, I'll try to answer the question for my friend and other interested readers of this issue of *JOMI*, in case a patient asks anyone the same question.

Interestingly, the question has also popped up frequently in various ads, infomercials, and testimonials about implants on the web. When I did a Web search on the phrase "implants stronger than teeth?" I found many websites answering a with confident "yes," as if there were no doubt! Some mentioned research and studies showing that implants are stronger than teeth "in many cases," but did not give reference information for specific, verifiable studies.

How could we verify claims that implants are stronger than natural teeth? First, I imagined how a magazine such as *Consumer Reports* (CR), which conducts tests of consumer products, might try to answer the question. Typically, *CR* compiles a large table listing each product and its performance in various tests. *CR* might rank the "strength" of natural teeth and implants of various brands. *CR* might do this on the basis of 1 or more well-defined, clinically relevant, quantitative performance metrics relating to strength. The tabulated metrics would likely come from 1 or more agreed-upon tests of strength.

CR could test whole teeth and implants, apart from any surrounding bone. However, *CR* might decide that it would make more sense to test the strength of natural teeth and implants together with their supporting interfaces, ie, with the periodontal ligament/alveolar bone complex of the natural tooth and the interfacial bone of the dental implant. This type of test, it could be argued, is more clinically relevant, since it more closely represents the way teeth and implants function in vivo.

However, the task would be so large and complex as to be beyond the scope of such an approach. Tests would have to be done for: *(1)* all the natural teeth in the adult mouth and *(2)* all of the dental implants on the market—no small undertaking. *CR* would have to apply a battery of structural tests, such as as torsion, tension, compression, shear, and bending tests, or rely on archival data. While one might predict that small cylinders of titanium would end up being structurally "stronger" (ie, capable of withstanding higher loads before failing) than irregular teeth in all types of loading, this remains to be seen.

If *CR* chose to study the teeth with their supporting interfaces, the scope of the testing would have to be expanded; the tests would have to account for the various sizes and shapes of all the natural teeth and all the implants, as well as the quantity and quality of surrounding bone, and the healing time of the bone, etc. Again, these would be structural tests, and this work would be no small undertaking!

Even if *CR* could do all of this, they'd still need to tell readers how to interpret all of the test results; they'd have to clarify what it would mean to compare, eg, the torque-out "strength" of a multirooted molar tooth with the torque-out strength of a single 3.75 × 10-mm screw-type implant in cortical bone. Moreover, *CR* would be obligated to explain the minimal clinically-relevant level of torque-out strength necessary, since clinical relevance would be the motivating force behind the entire exercise. (We wouldn't want to compare strength numbers without knowing the required strengths in real situations.) Given the complexity of the knowledge needed to understand such tests, it seems an unlikely undertaking for *CR*.

By now it may have occurred to savvy readers of *JOMI* that the field of dentistry doesn't yet have the database of tooth and implant strengths imagined in the preceding exercise. Although some data on torque-out tests for various dental implants in various types of animal bones are available, I was unable to locate comparable torque-out data for various natural teeth in human bone. One might suspect such data exist in view of the many tooth extractions performed every year. However, since clinicians don't normally extract healthy natural teeth from humans, whatever data might exist would most likely pertain to compromised natural teeth. Likewise, while I know there are some (limited) data for axial pull-out, push-in, and lateral-bending tests of oral implants in animal bones, I doubt that I could find comparable data for natural teeth. In light of the information we lack, I wonder how anyone can come to the firm conclusion that implants are "stronger" than natural teeth on the basis of structural testing.

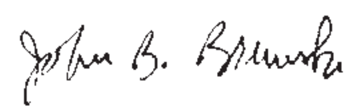
However, here is one way in which I could argue that implants are "stronger" than natural teeth: There is ample evidence that about 4 to 6 dental implants in either arch in a human are able to restore the function of the 16 or so missing natural teeth in that arch. From this clinical outcome, it appears that 4 to 6 implants can do the job of 16 (missing) natural teeth, allowing us to state that implants are "stronger" than natural teeth. But this argument is weakened when we consider that it's not known whether 4 to 6 natural tooth abutments would have worked as well as the 4 to 6 implant abutments to support the same sort of full-arch "hybrid" prosthesis that's used with implants. Likewise, it's not known whether 16 free-standing, single-tooth implants arranged in a one-for-one replacement of the 16 natural teeth would do as well as the 16 natural teeth. Until we have some data on these 2 situations, or at least until we know the individual load-bearing capacities of natural teeth and implants (which are largely unknown right now), I don't think we're justified in making the unqualified claim that "implants are stronger than natural teeth." But I would agree that the argument based on the use of 4 to 6 implants has some merit.

As Carl Sagan once noted, "Extraordinary claims require extraordinary evidence." Claims made in advertisements or on the Web that a particular titanium alloy is the "strongest metal on earth," or that tooth enamel has the "strength of steel" are extraordinary claims. Both of these claims, taken from actual ads, bring up the issue of intrinsic material properties. First of all, from reading the advertising material in its entirety, the titanium alloy noted is evidently Ti-6Al-4V. While this alloy is strong in terms of yield strength (896 to 1,034 MPa) and tensile strength (965 to 1,103 MPa), which are examples of intrinsic material properties, eg, properties that don't depend on the size or amount of material, this titanium alloy isn't the "strongest metal on earth," nor even the strongest implant metal: In fact, hot-forged Co-Cr-Mo alloy (ASTM F 799) has a greater yield strength (896 to 1,200 MPa) and a greater tensile strength (1,399 to 1,586 MPa).[1] Second, the typical tensile strength of dental enamel from humans is about 10 MPa[2] while the tensile strength of typical 316L stainless steel is 483 to 1,351 MPa, depending on metallurgical processing.[1] Hence, the claim that the enamel has the strength of steel doesn't comport with the data either. On the other hand, if one thinks it's fair to judge "strength" on the basis of material properties alone, then implant-grade titanium is stronger than the dentin or enamel of a natural tooth, and therefore "implants are stronger than natural teeth."

However, the ultimate strength of any loaded part—whether that part is an implant, a natural tooth, or a turbine blade—depends on both the intrinsic properties of the material and the shape and size of the part. The size and shape of a part can cause the part to fail even if the part is made of a "strong" material with high yield or tensile strength. For example, I could design a tiny implant made of a strong titanium alloy that would fail before a bigger implant made out of a weak polymer. Simply quoting intrinsic material properties such as yield, tensile, or fatigue strength is not sufficient to establish the "strength" of a part when it's used in some application.

While websites often simplify when they explain the basic concepts of implant dentistry and implant materials for the lay public, words such as "bioactive" and "bonding" ought to be explained in the interest of full disclosure. A website may, for example, describe titanium as "a bioactive metal" without adding the caveat from Albrektsson and Wennerberg[3] that "It has so far been impossible to prove the existence of bioactivity." Likewise, suggesting that the body is "tricked" into believing that the titanium implant is a tooth is a bit of a stretch. Implants are not attached to bone like a tooth—there is no periodontal ligament—so in that sense we haven't tricked the body into anything just yet. Finally, claims such as "the body…bonds directly to the implant surface with a bond that is even stronger than to natural teeth," also demand proof. Actually, based on the limited data we have,[4] the tensile and shear bond strengths for typical bone-implant interfaces are on the order of 0 to 4 MPa, depending mainly on the surface roughness. Meanwhile, the tensile and shear strengths of the tooth-periodontal ligament "interface" are about 1 to 3 MPa.[5,6] So to be fair and balanced, implants are "bonded" to bone with a strength that's about the same as that which "bonds" a tooth to bone. So in this sense, implants are not stronger than teeth.

In short, if friends ask you about advertising claims that implants are stronger than teeth, find out where they saw the advertisement in the first place and what evidence might have been presented to bolster the claim. In the meantime, if nothing else, do your own Web search on "implants stronger than teeth" and see what you find. Hopefully, all this may stimulate more research about implants, teeth and interfaces and lead to more truth in advertising on the Web.



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