

Primary Stability Versus Viable Constraint— A Need to Redefine



Any regular reader of the *The International Journal of Oral & Maxillofacial Implants*, or indeed of any other publication on dental implants, could not fail to have noticed how much attention has been focused on *primary stability*. The concept of primary stability is not new; as early as the 1970s there were studies emphasizing the need to establish mechanical stability to ensure uninterrupted healing of the bone.¹ This was most evident in the orthopedic literature as it pertains to hip prostheses.²

By the 1990s, numerous reports were being published on immediate loading of dental implants,³⁻⁶ and the groundbreaking work by Neil Meredith on the application of Resonance Frequency Analysis (RFA) came to the fore⁷⁻⁹ stating that achievement of implant stability was a prerequisite for long-term positive outcomes. At the same time, Meredith recognized that it was possible for clinically firm implants with poor axial stability to still be prone to failure.⁸ Of course Brånemark recognized this in his early work, proposing a period of submerged healing because of his concerns for any destabilization of the bone-to-implant interface during the early healing phase. However, today we all recognize that such protective protocols are frequently unnecessary, with widespread acceptance of not only transmucosal healing, but also immediate temporization and/or loading.

So how do we define primary stability? The simplest definition is one of mechanical friction between the implant and bone. Certainly we can all appreciate that this contrasts with secondary implant stability, which is achieved by biological integration, ie, osseointegration. The gradual shift from primary stability to secondary stability is critically poised at around 3 weeks. This is seen to be the least stable time point where viscoelastic stress relaxation of the bone along with remodeling results in a loss of primary mechanical stability,⁹ but with an as yet poorly established degree of secondary stability or osseointegration.

This is also apparent in RFA curves, which, like a heartbeat, always register a certain pattern in healthy bone that reflects this loss of stability at the third or fourth week, regardless of bone density.¹⁰

That said, we still need to define what constitutes primary stability, ie, that which sets it apart from biological integration. As stated above, mechanical stability occurs where a friction occurs between the implant and the surrounding bone, giving rise to a resisting torque at time of insertion. This resisting torque is proportional to the effort required to seat the implant or peak

insertion torque; they are in essence one and the same and depend largely on the characteristics of the implant, the density of the bone, and the differential size of the osteotomy as it pertains to the diameter of the implant. Mathematically it can be defined as follows:

$$\text{Resisting torque} = \frac{\mu * P * H * \pi * D^2}{2}$$

Where: $H * \pi * D^2$ = Surface area of implant in contact with bone where H = height of the implant cylinder and D = diameter of implant cylinder

P = Critical pressure on the bone

μ = Coefficient of friction

The important factor in this equation is P, the critical pressure on the bone, since high pressure results in unfavorable bone strain, particularly within the cortical compartment. However, the formula indicates that the resisting torque is proportional to the diameter (D) raised to the power of 2. This means that if you double the diameter, the resisting torque becomes four times higher. Put another way, if we use the same insertion torque for a 3-mm-wide implant and a 6-mm-wide implant, then the critical pressure P will be four times lower for the wider implant! For example, an implant of 3 mm diameter inserted into 1-mm-thick cortical bone with a torque of 20 Ncm will transmit the same pressure to the bone as an implant of 6 mm diameter inserted into 2-mm-thick cortical bone with a torque of 160 Ncm. (This assumes that 100% of the torque originates from the pressure on the cortical bone and that the contribution to torque from bone cutting, etc, is neglected.) Yet manufacturers persist in providing a single target value of insertion torque across the range of implant diameters they offer.

It is therefore reasonable to discuss the virtues of insertion torque and ask the pivotal question: Is insertion torque an appropriate measure by which to quantify optimal primary stability? After all, bone is a living tissue, so any measure of primary stability must also reflect the future viability of the bone.

It is clear that higher insertion torques fulfil the desire to achieve a high degree of mechanical stability as interpreted through manual perception. It is typical for manufacturers to provide some guidance on optimal insertion torque, with some implant designs being specifically tailored to deliver higher insertion torques, in excess of 75 Ncm. This yields a sense of comfort for the clinician that the implant is initially “stable.”

However, such a high torque has not been shown to be propitious to the surrounding bone. Numerous studies have been published which clearly demonstrate that the critical pressure these high torques create leads to microfracture of the bone,^{11,12} with a net resorption in the cortical zone^{11–13} and an unfavorable, indeed delayed healing process with reduced bone-to-implant contact.¹⁴ Such a response might well shift the onset for secondary stability and thereby delay or extend the period of potential vulnerability. This is clearly counter to the goal we are trying to achieve with immediate or even early loading protocols, whereby we want to transfer from simple mechanical fixation to full osseointegration in the shortest possible time.

The most fascinating aspect of this debate is the lack of correlation between insertion torque and the Implant Stability Quotient (ISQ) as measured by RFA, which appears to be counter-intuitive. How is it possible for an implant that is driven in at 30 Ncm to have the same ISQ as one that required 100 Ncm of torque? Nonetheless, the weight of the literature would seem to suggest this is the case.^{15–18} Since ISQ is measuring axial stiffness, it is clear that frictional rotational resistance is a completely different parameter. After all, I don't doubt we have all experienced the "spinner" (an implant that exhibits little or no rotational stability) that went on to osseointegrate, and there are a number of studies published which report high success rates for immediately loaded implants that were inserted with low insertion torque.^{19–22} By contrast, implants with an ISQ of less than 50 rarely go on to integrate successfully, and ISQ has been described as a good predictor of success.^{23,24} It is this dichotomy that has got me thinking and has led me to write this editorial piece. Could it be that axial stiffness is far more pertinent than rotational friction in ensuring an implant integrates? We already know from the literature that an implant can tolerate a degree of micromotion, thought to be circa 100 to 150 μm ,^{25,26} and this is in essence what ISQ measures. Studies have also demonstrated that insertion torque correlates closely to the degree of micromotion.²⁵ However, it is not the aim to seek complete elimination of micromotion, a valuable lesson learnt in orthopedics.²⁷ If it is possible to place an implant with lower insertion torque and still achieve axial stiffness with an ISQ > 60, surely this provides us with a more optimal evaluation of primary stability. Our goal must be the rapid onset of secondary stability, with minimal critical pressure to the poorly vascularized cortical bone, so that unfavorable resorptive responses and delayed healing are avoided. At the same time, we need to employ an objective measure of constraint that reliably ensures the implant can tolerate early or immediate loading, as was recently proposed by Barewal et al.¹⁷

I have labelled this objective measure *Viable Constraint* (vC), whose central purpose is to obtain a clinically relevant degree of stability while maintaining a low critical pressure on the vulnerable cortical tissues through which our implants are inserted. Bone is not wood and it is not inanimate – it would behave us all to remember this and avoid the carpenter's approach to implant dentistry.

So I would take this opportunity to ask that we think in terms of *Viable Constraint*. It will of course take controlled prospective studies to determine the optimal conditions for vC, but if I were a gambling man (which I most certainly am!), I would guess that for a 4.5-mm implant in bone with a cortex of < 1.0-mm thickness that a maximum torque of 20 Ncm and an ISQ of 60 represent the optimal measures we require to ensure safe immediate loading.

In the past we used to think length was important with implants, whereas today there is increasing focus on short implants. However, I would point out that a strong correlation has been shown to exist between ISQ and implant length,^{28–30} and as such, for immediate loading I also believe a longer implant with a higher ISQ, inserted at a lower insertion torque, will yield a more favorable outcome.

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