Fundamentals for Achieving the Consistent Skeletal Attachment of Implants

With the broad introduction of porous coated devices in the early 1980’s in total joint replacement came the realization that certain fundamentals must be practiced in order maintain and achieve consistent skeletal attachment. They are:

1) The geometric design and operative procedure must assure an initial mechanical stability of less than 100 um of motion between implant surface and host bone (Implant fit and fill) (1).

2) Mechanical stability should be maintained for up to 6-9 months to limit motion (<100 um) while the host cancellous bone integrates with the implant surface (2).

3) Limiting the gaps between implant surface and host cancellous bone to less than 50-75 um is essential to assure bone attachment and prevent fibrous tissue interposition between implant and bone. (3,4)

4) Understanding that when placing an implant in cancellous bone that cancellous bone does not heal like cortical bone (3,4).

5) Cancellous bone healing occurs in an appositional manner with very little (<1%) callous formation. This makes cancellous bone attach slowly to the implant surface and/or porous coating compared to fractured cortical bone. (3,4) Cancellous bone does not have a periosteal membrane.

6) The implant surface should be rough and/or porous to achieve and maintain skeletal interlock (3-5).

7) Skeletal interlock can be achieved by impacting a porous coating into the bone.

If these seven fundamentals are achieved then a large body of the orthopaedic literature supports that skeletal attachment can be consistently achieved and maintained in cancellous bone clinically.

There is another major issue of which spine surgeons need to be aware. There is currently controversy as to whether a disc spacer or replacement should be attached to the endplate (calcified fibrous cartilage) to secure the devices to the vertebral body or to the cancellous bone.
Studies have recently been conducted (6,7) which have demonstrated that calcified fibrocartilage does not appear to have the biological capacity to remodel or ingrow into a porous coating or osseointegrate with the implant surface. This is important information when considering the need for durable implant attached to the vertebral body.

*Implant Modulus Compared to the Modulus of Bone*

There are frequent arguments in the field of biomaterials and orthopaedics that the modulus of the biomaterials used in an implant may have a significant impact on the ability to effect bone remodeling, skeletal attachment, and bone maintenance. Jensen, et al. (8) performed structural analysis on the human vertebra. They measured the Young’s modulus of the cancellous bone to be 3.8 (GPa). If one measures the Young’s modulus of any implant construct used in the spine, made from any biomaterial, it is generally found that the device will be anywhere from 5 to 10 times the modulus of bone.

In total joint replacement, the Young’ modulus of an implant based on geometry and material type (these two factors can not be separated), has for the most part, shown not to be a factor in bone maintenance, stress shielding, and skeletal attachment. It remains the seven factors stated above that are the most significant design issues in obtaining the long term durable skeletal attachment of implants.

It is also important to note that it would more likely be clinically concerning to have biomaterial at the same Young’s modulus as cancellous bone, since bone remodeling is considered to be initiated by the microfracturing process. If the biomaterial construct were the same Young’s modulus as bone and form microfractures, and the material had not been completely incorporated by the host bone, then the construct would collapse. This occurs frequently in bulk allograft constructs, which are closer in Young’s modulus than other man made biomaterials.

I would highly recommend that every orthopedic spine surgeon read the excellent text book (*Bones*) written by John D. Currey (9), if they are concerned about the relationship of implant modulus to cancellous or cortical bone. Finally, if this argument remains a concern, then the manufacturer should provide the modulus of the device if requested to compare to the modulus of human bone tissue.

Finally, the use of autograph cancellous bone chips placed on the resected cancellous bone surface of the vertebral resected surface at the time of implantation has been shown to reduce gaps between the implant surface and host bone and can provide up to 3 times the amount of bone around the periprosthetic interface to support durable implant attachment and interface mechanical stability(10).

References:


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