BIOLOGICAL BASIS OF DENTAL IMPLANT

INTRODUCTION

There have been a number of publications that present information regarding the response of bone to titanium root form implants and the interface that develops between the implants and bone.1-10

To develop an understanding of the histopathology of alveolar bone as it responds to implants, it is necessary to accept the concept that the biologic activity of bone during growth and aging, and following surgical and prosthodontic procedures, is one of constant dynamic activity. Bone, in general, and alveolar bone in particular is always undergoing cyclic resorption and remodeling during the lifetime of the individual. These periods of remodeling are the result of various factors including vascular changes, inflammation, and the application of forces.1

When an endosseous root form implant is placed into bone, contact with the surrounding bone is achieved as part of the surgical placement technique. This initial contact creates primary stability for the implant. Even with copious irrigation and using a slow revolution of the cutting instrument, some necrosis of bone occurs when the implant site is prepared. This necrotic osseous surface must be remodeled, resorbed, and rebuilt. A viable bone-to-implant interface subsequently develops around the entire implant with the bone maintaining dynamic activity.

The response of bone to dental implants is different from the response of bone to occlusal function as transmitted by the roots of teeth. The occlusal forces placed on teeth and transmitted to bone produce similar and yet important dissimilar reactions to those forces placed on bone by root form implants1 (figures 1A & 1B).

OSSEOINTEGRATION

Brånemark introduced the term osseointegration and defined it “as a direct structural and functional connection between ordered, living bone and the surface of a load-carrying implant.”10 Another definition of osseointegration11 indicates it is “contact between normal and remodeled bone with a metal implant surface without the interposition of non-bone connective tissue.”

The Glossary of Prosthodontic Terms12 does not define osseointegration. Instead, the reader is referred to the term “osseous integration” which is defined as “the apparent direct attachment or connection of osseous tissue to an inert, alloplastic material without intervening connective tissue.” All of these definitions indicate there is contact between the implant and bone. It must be realized that there is never 100% bone contact at the implant interface.123

The range of percentages of the implant surface contacting bone matrix varies between 10% and 90% according to different investigators.1-7 Also, the last two definitions indicate there is no connective tissue located between the implant and bone. These definitions were written to differentiate titanium root form implants from other types of implants such as subperiosteal implants where a layer of connective tissue develops all around the implant metal. It is important to remember that with titanium root form implants the marrow vascular spaces contain
connective tissue that should be considered part of bone since it is an integral component of cancellous and woven osseous tissue.

DEVELOPMENT OF THE BONE-TO-IMPLANT INTERFACE

Implants Placed Into Healed Edentulous Ridges

Implants are frequently placed into edentulous ridges that have healed following extraction of the tooth/teeth. When the bone of a healed ridge is prepared for placement of a root form implant, there is bleeding into the marrow vascular spaces and into the site prepared for the implant. The implant is placed into the osteotomy site, creating some direct bone contact and stabilization of the implant. Blood from the osteotomy site coats the implant and fills spaces between the implant and bone. The blood undergoes coagulation and clot organization prior to formation of pre-osseous matrix and bone formation.

Implant Placed Into Extraction Sockets

Implants are also placed into fresh extraction sockets. Except for the apical or the apical-lateral portion of the implant, much of the metal surface may not be in contact with the bony walls of the socket, but in juxtaposition to the surrounding organizing clot in the socket which must continue to undergo the organization process and all the histologic changes necessary prior to the formation of pre-osseous matrix and bone formation. In humans, this process takes approximately 4 to 6 weeks for the socket to fill with cancellous bone (figure 2). Such cancellous or woven bone has wide marrow vascular spaces and is incompletely calcified. It must undergo further remodeling and “stiffening” prior to forming the osseous support which is necessary for full functioning of the implant. Such cancellous bone will undergo remodeling to form a more lamellated structure (figure 3). With increased remodeling and with proper prosthodontic function, the bone-implant interface will tend to show very mature osteonal and lamellated bone (figure 4).

Bone Necrosis

About 1 millimeter of cortical bone adjacent to the osseous wound (osteotomy site) undergoes postsurgical necrosis in spite of careful surgical technique. This bone must be replaced with vital bone to strengthen the interface and provide tissue that is capable of long-term maintenance.4

Interface Phase Development

Three phases have been described in the development of the bone-implant interface.5 The first phase is called the stabilization phase where subendosteal and subperiosteal calluses form and adhere to the implant surface. The bone is relatively low in density at this time (woven bone) and forms rather rapidly.4 The critical stabilizing role of calluses has been documented.6

Once the implant is stabilized, the process of resorption begins. This second phase is called the strength phase where stronger, weight bearing bone is formed (lamellar bone). Osteoclasts resorb nonvital bone and restore it with new lamellar bone.5 The lattice structure of the callus
provides space for lamellar bone and once this space is filled with well-organized lamellae, the bone is able to bear loads.4

The third phase is called the durability phase where there is extensive remodeling occurring and additional strength is developed. With remodeling and proper prosthodontic function, the interface bone will tend to show very mature osteonal and lamellated bone (figure 4). Bone remodeling and changes occur during the lifetime of the patient and the lifetime of the implant(s) and the prosthesis. Changes in the prosthesis can bring about changes in the bone and both the prosthesis and bone can contribute to long-term success and can conversely contribute to failure.

Remodeling Rate

Human cortical bone normally remodels at a rate of about 2-10% per year depending on the site and age of the patient. Cortical bone in the alveolar process may exhibit a turnover rate of up to 10% per year in some people. Cortical bone in other areas of the body turns over at a rate of about 2-5% per year. Trabecular bone turns over at a higher rate (20-30% per year). In a study of remodeling, the bone turnover rate was found to be substantially higher within 1 millimeter of the bone-implant interface.7

Characteristics Of Bone Adjacent To Implants

The hardness of the bone immediately adjacent to implants was found to be significantly lower than bone farther away from the implant.8 There was also less microdamage in the more compliant bone adjacent to the implant than in the older bone that is located some distance away from the implant.9

Physiologic Mechanism Of Osseointegration

It has been suggested that the physiologic mechanism for maintaining osseous integration (osseointegration) is a sustained elevation in remodeling adjacent to the bone-implant interface.7

CONCLUSIONS

In reviewing the biologic basis for osseous response to root form implants, the dynamic nature of bone and its ability to respond to changes is a key factor. This remarkable ability, if properly used by the clinician, can bring about long-term success.