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March 1, 2012
“Hydroxylapatite (HA) Coated dental implants have been successfully used for almost 25 years.

It has been well documented in the scientific literature over the past 25 years that HA coated implants have the following advantages over uncoated implants.

- Enhanced osseointegration at earlier stages,
- Greater initial implant/bone strengths,
- Quicker initial implant/bone attachment,
- Higher initial success rates,
- Withstand greater immediate loads,
- Achieve better bone contact in less dense and decreased amounts of bone

From a clinical perspective, I have personally placed over 10,000 HA coated implants with a 98+% success rate. The few times I placed uncoated implants resulted in more failures, loss of revenues and unhappier patients. There is no question in my mind that a HA coated implant is more successful, can be loaded earlier and develops a quicker, stronger bond with the bone than an uncoated one.

While there have been claims of coatings shearing from the implant and/or the coatings dissolving from the surface of the implant, my experience and the literature do not support these claims. It is important to realize that all HA coatings are not the same. HA coating of implants is both an art and a science. HA coatings can have a shear strength from 1,800 PSI for TCP coatings to 8,000 PSI for HA coatings. The quality of the coating is dependent upon the experience and quality control of the coating company. The quality of the HA coating depends upon a number of factors including;

- The Coating Technique,
- Degree of Crystallinity
- Density,
- Purity,
- Chemical Composition.
- Macrotexture of the Implant Surface,
- Coating Thickness
- Dissolution Rate,
- Bond Strength.

Plasma sprayed HA coatings of dental implants and joint replacement implants performed by reputable coating companies have consistently performed as good or better than uncoated implants. The standard in the industry is still Plasma Spray although there now exists numerous methods to coat HA onto implants including;

- Plasma Spray,
- Electronic Spray Deposition,
- Pulsed Laser Deposition,
- Micro-arc Oxidation,
- RF Magnetron Sputter Deposition,
- Sol-gel Film,
- Spark Discharge,
- Chemical Vapor Deposition,
- Ion Beam Assisted Deposition,
- Hot Isostatic Pressing.
As well, numerous HA coatings are available including:

- Fluorapatite,
- Dicalcium Pyrophosphates,
- Chemical Made Apatite,
- Nano-Structured Ceramics,
- CaTiZirconium Phosphates,
- CaTi Surfaces,

While these new coatings show promise, the standard in the industry today is the Plasma Sprayed HA coating performed by a reputable, experienced coating company.

Simpler Implants contract all their coatings to one of the largest HA coating companies in the world who have been in the coating business for over 25 years. They coat hips and knees for the medical community as well as dental implants for the dental community. This company has ISO 13485:2003 certification, the highest quality control standards in the world. The dual coated Simpler Implants have a shear strength close to 8,000 psi. The bone will fracture before the coating will come off.

There is no question that an HA Coated Narrow Diameter implant will out perform and uncoated one. The following pages contain abstracts from over attached is a comprehensive list of over 125 scientific articles from the past 25 years which substantiate the above claims and comments.

Dr Harold Bergman, DDS, DiplOS&A, MScD(Path), MRCD© - March 1, 2012
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CLINICAL STUDY OF THE PLACEMENT OF 635 ANCHOR HA COATED IMPLANTS INTO 263 PATIENTS,
Dr. Harold Bergman

635 Anchor HA Coated Implants were placed in 263 patients in varying locations in the anterior and the posterior of the maxilla and the mandible. The surgical approaches used were fresh extraction sites, “cookie cutter” or tissue punch, limited exposure flaps and full periosteal flaps. 35 of the implants were placed into first extraction sites at the time of extraction.

After the four to six month healing period, 556 of 559 tested positive for osseointegration giving a **99.46% success rate**. One implant failed to osseointegrate due to “operator error” in that the implant site preparation was oversized and the implant was “loose” in the socket. Two failed in one patient in the mandible due to placement into an infected extraction site. All 556 were fitted with various prostheses including crown, bridges, overdentures, Doldar Bars and fixed dentures/bridges.

This study shows that the **ANCHOR Hydroxylapatite Coated Dental Implant System osseointegrates with a very high rate of predictability** while using simplified surgical techniques and prosthetic procedure. As a result, it falls within the capabilities of most general practitioners enabling them to perform this technique in their dental office with only minimal training.


Clinical data suggest that HA-coated implants may be better treatment modalities than uncoated titanium implants (1) in type IV bone, (2) in fresh extraction sites, (3) in grafted maxillary and/or nasal sinuses, or (4) when using shorter implants (less than or equal to 10mm.)

**Microbial adhesions:** microbial colonization of HA-coated implants and titanium implants are not significantly different but similar. There does not appear to be sufficient evidence that HA surfaces are subject to colonization by selective pathogenic microflora, any more so than titanium implants or natural teeth.

**Susceptibility to Rapid Peri-implant Osseous Breakdown:** Binding of bacterial lipopolysaccharides can be removed with a 60 second wash of 1% citric acid without substantial removal of the HA coating.

Coating Failure: In vivo cases of HA-coating-titanium interface fractures that are associated with implant failure seem to be extremely rare. Of 673 HA-coated implants, **not a single implant failure was attributed to HA-coating dissolution or HA-coating-titanium interface fracture.**

**Rapid Osseous Adaption:** Bone adapts more rapidly to HA-coated implants than to titanium implants. In dogs, HA-coated implants demonstrated nearly complete interfacial mineralization at 10 weeks, in contrast to uncoated commercially-pure titanium implants of identical shape in which only partial bone complete interfacial mineralization was observed. 1,340 osseointegrated endosseous implants at the time of uncovering reported that the **mobility of HA-coated implants was significantly less than titanium implants**, as measured by the Periotest.

The study compares the histologic response to a hydroxylapatite (HA) coated titanium implant with that of two of uncoated titanium endosseous dental implants in dogs. The three surfaces examined included HA coated titanium, smooth titanium, and rough or grit blasted titanium without the mechanical benefits of threads, flutes, or holes included in the implant design. Significant differences were observed in the approximation and rate of bone formation on the implant surfaces. In this study, bone formation and maturation clearly occurred at a faster rate and at earlier periods on HA coated implants than on the noncoated implants. And, in contrast to the noncoated implants, the HA coated implants showed an osteoid layer forming in a coronal direction. This may be beneficial when placement of an implant results in thin crestal bone or even bone dehiscence from the chipping of crestal bone by burs. The HA implants resulted in a superior bone bonding, earlier biointegration, a more complete layer of lamellar bone surrounding the HA coating, and better maintenance of crestal bone.

LOADED HA COATED & GRIT BLASTED TITANIUM IMPLANTS IN DOGS, M.S. Block, J.N. Kent, I.M. Finger, G. Mohr, Proc. World Biomaterials Congress April 1988, Kyoto, Japan (Sub. for Present)

This study reports the histological and clinical features of loaded HA coated dental implants as compared to grit blasted titanium implants in dogs. When exposed at eight weeks after surgery, all implants were non mobile with no radiographical or visible discernable bone loss adjacent to the implants. Abutments were screwed to place and impressions were taken. Bridges were placed two weeks later, and all dogs were placed on regular dog chow diet. Ten month specimens showed a statistically significant difference in the amount of bone on the implant’s surface. The HA coated implants had 66.4% of their surface directly in contact with bone whereas the grit blasted titanium implants had 50.2% of their surface covered with bone.

INDICATIONS AND CONTRAINDICATIONS, Michael Block, DMD, Symposium on HA coatings, 1995

Why do implants fail? Iatrogenic factors often are involved: 1) malposition of the implant; 2) unseated abutments; 3) occlusion; 4) poor hygiene; 5) labial defect at time of placement; 6) posterior cantilevers; 7) soft bone in the posterior mandible; 8) lack of attached gingiva; 9) opposing natural dentition with occlusal surfaces.

HYDROXYLAPATITE COATINGS ON DENTAL IMPLANTS (BONE RESPONSE TO HA), Philip J. Boyne, Journal of Oral Implantology, Vol. XX, No.3, 1994, 227-239

Cylindrical implants perforating 5-6 mm through the cortical bone, whether HA-coated or not appear to stimulate the subperiosteal cortex to form bone when a minimal 2 mm perforation occurs. Perforations up to 5 mm were partially covered with bone. Open ended implants such as ITI and Core Vent did not produce bone formation. Likewise, screw type implants had minimal bone. It would appear that in perforations of the cortex, shape of the implant is the limiting factor in effecting optimal bone repair.
HYDROXYLAPATITE COATED TITANIUM FOR ORTHOPAEDIC IMPLANT APPLICATIONS, Stephen D. Cook, Ph. D; John F. Kay, Ph.D; Kevin A. Thomas, Ph.D; and Michael Jarcho, Ph.D., Clinical Orthopaedics and Related Research, 1987.

The interface mechanical characteristics and histology of CP titanium and hydroxylapatite (HA) coated Ti-6Al-4V alloy were investigated. Interface shear strength was determined using a transcortical push-out model in dogs after periods of 3, 5, 6, 10 and 32 weeks. The HA-coated titanium alloy implants developed 5-7 times the mean interface strength of the uncoated, bead-blasted CP titanium implants.

The mean values for interface shear strength increased up to 7.27 MPa for the HA-coated implants after 10 weeks implantation, and the maximum mean value of interface shear strength for the uncoated CP titanium implant was 1.54 MPa after 6 weeks implantation. For both implant types there was a slight decrease in mean shear strength from the maximum value to that obtained after the longest implantation period (32 weeks). Histologic evaluations in all cases revealed mineralization of interface bone onto the HA-coated implant surface, with no fibrous tissue layer interposed between the bone and HA visible at the light microscopic level. The uncoated titanium implants had projections of bone to the implant surface which were separated by a thin fibrous layer in most areas, although apparent direct bone-implant apposition was observed in some locations. Measurements of the HA coating material made from historic sections showed no evidence of significant HA resorption in vivo after periods of up to 32 weeks.

The HA coating is a tough abrasion resistant layer, which does not sustain damage under normal implant handling conditions. In vitro testing has indicated an approximately 17 MP coating to substrate shear strength.

Two significant observations concerning the strength data can be made. First the HA-coated implants had significantly greater average interface strength than the uncoated implants at each of the time periods, indicating that the HA-coated implants were always more tightly bound at the bone-implant interface than were the uncoated implants. Perhaps a more important observation is that the HA-coated implants developed approximately 3 times the mean interface shear strength of uncoated implants after only 3 weeks, and approximately 5-7 times the mean attachment strength of the uncoated implants at all time periods thereafter.


In-vivo interfacial mechanical characteristics and histology of CP Titanium Hydroxylapatite (HA)coated titanium using the transcortical implant model were investigated. The implants were cylindrical, with identical surface characteristics (B blasted titanium vs. HA coating) to eliminate the surface texture from consideration in evaluating the data. Animals were implanted using a traumatic manual reaming techniques where a uniform and precision interference fit was obtained; sacrifice at five, 10, and 32 weeks provided specimens for mechanical testing and histological analysis. Histological evaluations, in all cases, revealed mineralization of interfacial bone directly onto the HA coated implant surface, becoming part of the implant composite system. The uncoated titanium implants had a thin fibrous interpositional layer present in most areas, with projections of bone in direct opposition to the implant surface in a limited number of locations around the implant perimeter. The HA coated system developed an average of five to eight times the mean interfacial strength of the uncoated, B blasted CP titanium system. Measurement of the HA coating thickness at each time period revealed no statistically significant change in the coating thickness, up to 32 weeks in situ. While the implants in this model do not carry physiological loads, they do represent models for the healing sequelae associated with two stage dental implants where endosseous implant bodies are installed and remain unloaded for a specified healing period.
Hydroxylapatite Coatings

ilaterally spaced approximately 1.5 cm apart in the mid-diaphyseal area of the femur. After 2, 4, 6, 8, 12, 18, 26 and 52 weeks, the femurs were harvested. Each implant was isolated and bisected perpendicular to the implant’s long axis to yield one HA-coated and one uncoated (control) pushout sample. The results indicate that, at the time of implantation, the presence of HA-coating and percent bone ingrowth significantly affected interface attachment strength. Mechanical testing results revealed enhanced attachment strength for the HA-coated samples, as compared with the uncoated samples. Both the HA-coated and uncoated porous implants developed interface strength rapidly during the 2-to 8-week period. The rate of increase in attachment strength was greater for the HA-coated implants, with HA-coated samples demonstrating strengths after 5 weeks that exceeded the uncoated strength after 12 weeks. All implants showed a decrease in attachment strength from 26-52 weeks.

The results of quantitative histologic analysis also demonstrated a greater percentage of bone ingrowth for the HA-coated samples as compared with the uncoated samples at all time periods. A greater proliferation of bone ingrowth was associated with the HA-coated samples, particularly at the early implantation period. Additionally, the HA-coated samples consistently exhibited percent bone ingrowth that exceeded that of the uncoated samples at the next longer time period. Qualitative histologic evaluation demonstrated that early ingrowth (up to 6 weeks) was primarily woven bone that remodelled to lamellar bone at later time periods. The percent bone ingrowth for the HA-coated implants increased significantly with time from 4 to 6 weeks and 18 to 26 weeks. There was no evidence of disruption, mechanical failure, or biologic resorption of the HA-coating observed in any samples at any time. (Mark Mehrali)

The results of this study demonstrate that HA coated metal appears to be a viable alternative for biological fixation imparting a chemical rather than mechanical type of interlocking. The HA appears to prove an osteophilic type surface which decreases the time to reach maximum interface strength and increases the rate of bony adaption.


The results of thousands of HA coated implants at greater than 5 year follow-up have consistently shown survival rates in excess of 90%. The addition of surface threads, grooves and dimples did not significantly affect axial pull-out and torsional interface attachment strength, although the dimpled implant was stronger in axial shear than the other designs. This unexpected finding may be attributed to the lack of bone growth into and filling the surface textures.


HA-coated and grit-blasted (non-HA-coated) titanium dental implants were placed in healed extraction sites of canine mandibles. Mechanical testing at six weeks postop showed a 76.9% improvement in the maximum torsional interface strength in the HA-coated implants.


This study disputes the case reports that have argued that HA coatings of implants increase late implant failures.
The results of this study indicate that the HA coated titanium system provides an osteophilic substrate for bony proliferation. While the results obtained indicate CP titanium is a biocompatible metal that elicits no acute inflammatory response, the ability to deposit osseous tissue on two surfaces (the bone surface and the implant surface) may provide the mechanism for accelerated tissue adaption for the HA coated system.


The objective of this study was to evaluate the effect of hydroxylapatite (HA) ceramic coating on the ultimate attachment strength, the rate of development of attachment strength and the degree of bone ingrowth and/or apposition to implant surfaces. The material systems evaluated included: multi-layer porous CP titanium coated titanium alloy, two textured surfaces and dense surfaced implants of CP titanium and Co-Cr-Mo alloy; all implants were tested with and without the HA coating. The HA coating was applied by a plasma spray process, producing an approximately 50 micron thick dense layer. The implant systems were evaluated by transcortical surgical placement in adult mongrel dogs. Radiographic evaluations were made throughout the course of the implantation periods which included 3, 5, 10, 12 and 32 weeks.

Results of the mechanical testing for the porous system with and without the HA coating showed that the long term maximum interface strengths were equivalent at about 20 Mpa; however, the rate of development of the maximum interface strength was approximately halved. This time period was approximately 3-6 weeks for the HA coated porous titanium systems as compared to the 6-12 weeks for the non-HA coated system. The dense titanium and Co-Cr systems with HA coatings showed an approximately 2-3 times increase (8-9 MPa vs. 2-3 MPa) in interface attachment strength when compared to the non-HA coated systems.

Histologically, the HA coated porous systems exhibited an increased amount of bone ingrowth and degree of mineralization at early time periods compared to the non-HA coated systems; however, they became equivalent at later time periods. A thick fibrous layer, 1-2 cells layers thick, separating the ingrown bone from the implant surface was common in non-HA coated porous systems. The HA coated porous systems, demonstrating no such fibrous tissue layer, appeared to be directly mineralized to the implant surfaces. In addition, in areas of non bone ingrowth, a thin osteoid type layer was present on the exposed HA-coated implant surface.

This was not observed in the non-HA coated systems. Measurements of coating thickness changes as a function of time showed at all time periods the coating thickness remained at approximately 50 microns.


The purpose of this study was to investigate whether the use of plasma-sprayed HA coatings on spherical bead porous-coated implants can utilize the beneficial biological properties of HA coating without inherent mechanical limitations of the HA-metal interface. The effects of HA coating on the degree of bone ingrowth, maximum interface shear attachment strength, and rate of development of attachment strength were evaluated.

Cylindrical implants were fabricated by the sintering of gravity-compacted spherical Co-Cr-Mo particles 500-710 mm in diameter. Implant dimensions were 5.95 mm in diameter and 18 mm in length. HA coating was applied to one half of each implant by means of a modified plasma-sprayed process; its thickness was 25-30 mm. The implants were placed in skeletally mature mongrel dogs. Each animal received five transcortical implants.
Dense, sintered, push-in, HA implants were inserted transmucosally in dogs with initial retention obtained by pressure fit only. The implants were loaded from time of placement. As a rule, the implant cylinders became rapidly fixed, even though no specific precautions were taken for protection during the healing period. Most of these transmucosal implants showed a healthy mucosa. As a rule, the endosteal parts of the implants were completely covered with bone tissue with no intermediate connective tissue layer. The HA-coated implants had bone in direct apposition to their surface with no fibrous tissue interposition. The grit-blasted implants also had regions of direct bone-implant apposition, but these areas were limited to a smaller proportion of the total interface area. There was no evidence of breakdown or change in thickness of the HA coating.

Apparently, bone tissue can handle these biomechanical forces without any resorption processes. Implants can withstand heavy loading if there is an intimate bone contact without an intervening connective tissue layer. Implant micromovements during healing prevent a direct bone bond. However, dense HA implants can develop a direct bone contact without initial fixation and without precautions for immobilization or initial mechanical loading in contrast to titanium implant materials. **In implants with healthy mucosa, there were an appositional and upgrowth of bone, extending about 2mm above the alveolar bone level.** This phenomenon was always accompanied with connective tissue attachment, attachment of gingival fibers, and a real gingival attachment apparatus which has been developed at the implant, similar to natural teeth. However, implants surrounded with inflamed gingiva showed decreased bone support.


Implantation in excavated bone tissue resulted in new bone directly deposited against the implant surface. When the implants protruded from the bone surface, bone appeared to grow up to the edge of the protruding part of the implant. Very strong bonding developed; push-out tests indicated that the bone fractured, although never at the interface. Histological studies showed that a sleeve of newly formed bone closely encased the implant, regardless of shape. It was concluded that dense hydroxylapatite ceramics are fully compatible with the tibia of the rat and that no degradation of the implant material occurred for intervals of up to 6 months after implantation. **The very strong bonding without mechanical retention indicated continuity between artificial hydroxylapatite and natural bone.**

We will only discuss the results of research concerning the development of the hydroxylapatite-titanium implant in so far as they relate to the direct bonding of hydroxylapatite to human alveolar bone. Mascropic inspection of horizontal sections through human biopsies consisting of removed implant material with attached bone showed direct contact between alveolar bone and implant material at the interfaces. Microscopic evaluation confirmed this finding. At the bone side of the interface, osteocytes were observed close to the implant surface.

**Examination by transmission electron microscopy** of the areas of direct bone implant contact showed an intimate relationship between collagen fibrils of the bone matrix and the hydroxylapatite crystals of the ceramic implant material. Individual crystals could be seen to be interspersed with collagen fibrils of the bone, thus forming a strong interfacial bonding layer. The collagen fibrils in the bone matrix were mostly oriented parallel to the implant surface and consisted of several interwoven layers.
Smooth Cylindrical Design of the Implant: It is known that local compression of bone leads to resorption, while tension leads to bone apposition. Mohammed et al. performed photo-elastic stress analysis of single-tooth implants. They found that the design of the root of the implant is of importance with regard to the distribution of the (compressive) chewing force to the adjacent alveolar bone. A smooth cylindrical design of the endosseous “root” portion of the implant results in a more favourable stress distribution, both in the alveolar bone and the implant, than conical, blade or natural tooth root configurations. It can therefore be concluded that an endosseous implant with a smooth cylindrical shape has a maximum so-called mechanical compatibility with bone. Smooth cylindrical design of the implant is important for the clinician because it implies that the hydroxylapatite-titanium implant is easy to insert in alveolar bone without undue trauma. Trauma is caused in the case of other implant designs which must be screwed or hammered into living bone.

Strength of the Implant: The implant is inherently strong because of its titanium core. Recent advances in adhesive composites containing hydroxylapatite particles which bond to hydroxylapatite as well as to titanium have made the joining of the 2 materials possible without the difficult procedure of sintering hydroxylapatite ceramic to metal. The compressive strength of the ceramic is approximately 400mN/m², while its tensile strength is approximately 200mN/m². A mantle of 0.75mm of hydroxylapatite around a metal core is sufficient to prevent breakage according to our research in patients.


Skeletal fixation of permanent implants by new methods such as fixation by mechanical interlocking of bone with porous prosthetic coatings or chemical bonding with bioactive materials shows growing potential. This paper reports on the resulting skeletal fixation of a combined porous and bioactive material. Metal plugs with a porous metal fibre coating impregnated with hydroxylapatite were implanted for 2, 4 and 12 weeks and were compared to the parent porous, nonbioactive, metal fibre material. Statistical analysis of the interfacial failure shear stress, as obtained by mechanical testing, shows there is a marked influence of hydroxylapatite impregnation on the rate of bone ingrowth and the strength of the interfacial bond the few weeks following surgery. Microscopic examination reveals that the apparent stimulation of bone ingrowth into the surface pores of the implant is the reason for the increased rate of bond formation.


The object of this study is to assess the effect of hydroxylapatite (HA) coatings on the corrosion behaviour of cobalt chrome alloy specimens, comparing the characteristics with uncoated identical alloy. Cyclic potentiodynamic polarization tests and constant potential tests were performed on both materials, with sterile calf serum and Ringer’s Solutions as electrolytes. An analysis of the electrolytes was conducted by atomic emission spectrometry to determine the corrosion rates. The results of the cyclic potentiodynamic polarization data indicate the typical response for the cobalt chrome molybendum alloy. The uncoated samples showed similar results with slightly more erratic behaviour. As no historessus was observed for either type specimen, no pitting corrosion had occurred. The constant potential tests for the uncoated cobalt alloy indicated corrosion rates about an order or magnitude higher than those for the hydroxylapatite coated allow samples. The chemical analysis of the cobalt test electrolytes had concentrations 30 to 80 times higher than the HA coated samples. An interesting observation was the decrease in calcium apparently deposited on to the surface of the sample, consistent with in-vivo results showing a net deposition of calcium materials on the surface of implanted hydroxylapatite. The results of these studies indicated HA coated metal has the potential to decrease ion leaching from an exposed metal surface when implanted in the body.
TISSUE, CELLULAR AND SUBCELLULAR EVENTS AT A BONE-CERAMIC HYDROXYLAPATITE INTERFACE,
Journal of Bioengineering Vol.1, pp. 79-92

A new polycrystalline form of hydroxylapatite, durapatite, has been examined as a cortical bone implant in dogs. Utilizing histological and electron optical techniques, it has been found that durapatite does not elicit a foreign body response and that all new bone surrounding the material is normally calcified. Bone was found to strongly adhere to durapatite and preliminary evidence suggests this bonding may be due to direct chemical attachment of bone to the material.


Apatite ceramics composed of synthetic hydroxylapatite, were implanted in mandibles of adult dogs. The histological observations indicated that the apatite ceramic was closely contacted with newly formed bone tissue without any rejection phenomenon up to 2 weeks. An electron micrograph of non-decalcified ultra-thin section at 8 weeks showed that the apatite ceramic was directly bonded to newly formed bone and the mineralized bone tissue was grown into the micro pores of the ceramics independent on the pore size. It seemed that the outer surface of the apatite was exchanged by bone tissue. From these results it was considered that the apatite ceramic was a successful implant material in dental and surgical fields.

A NEW CONCEPT FOR NON-CEMENT FIXATION OF ORTHOPAEDIC DEVICES, John F. Kau, Techniques Orthop, 1987; 2 (1); 1-6; Aspen Pub. Inc.

Due to their similarity to the major mineral constituent of bone, synthetic ceramic hydroxylapatite implants have been shown to provide strong attachment to hard tissue via chemical bonding mechanisms. Clinical experience using HA coated revision stemmed prostheses supports the positive findings of earlier animal investigation, where decreased time to healing and the development of stress-transferring trabeculae to the implant surface were observed despite minor imprecisions in the initial fit.

Bone is composed of approximately 60% to 70% mineral and 30% to 40% organic matrix (collagen); it is generally accepted that the major mineral constituent of bone mineral is hydroxylapatite, with minor amounts of several adjunct constituents present in variable proportions. The hydroxylapatite in bone mineral is in the form of tiny elongated crystals so small that 40,000 would have to be placed end to end to equal one millimeter. Though small, these crystals stiffen the softer collagen matrix in a way not unlike the glass fibres stiffen the softer plastic in fibreglass materials.

“Mineralization of bone” as it matures is actually the maturation of the crystalline (mineral) part of bone. The embryonic bone mineral first produced in any new bone formation is variable in composition and relative proportion. It then matures through additions to the crystal structure to form a well-characterized, calcium-deficient apatite.

There has been recent concern and laboratory investigation regarding the release of metal ions into remote and surrounding tissues as a result of their implantation into the hostile environment of the body. Again, titanium appears to provide a high level of corrosion resistance and minimal ion release. Given the described strength and liabilities of metals and ceramics, combining these materials to form a composite would appear attractive as a materials system for total joint replacement devices.
Hydroxylapatite coating has been applied to metallic substrates using a modified plasma spray process. Mechanical tests on coated metallic substrates have demonstrated adequate mechanical properties when appropriate design considerations are addressed. Shear strength for these coatings is over 2,500 psi. Adding macroscopic surface texture to the implant in the form of grooves more than doubles the shear strength to 6,000 psi because pure shear stresses are avoided and mechanical interlock occurs.

Animal studies indicate a faster and stronger attachment of bone to the hydroxylapatite coated implants when compared with uncoated devices. In one study midly loaded transcortical implants, hydroxylapatite-coated titanium developed interfacial shear (pushout) strengths three to four times as large as uncoated titanium implants. The effect of macrotexture in the form of simple grooves almost doubled the pushout strength to approximately 1,800 psi. Histologic analysis confirmed the increase in fixation strength and decrease in time for attachment, allowing deposition of new bone on both the bone of the prepared implant site and the surface of the device.

A fourfold to tenfold increase in implant strength has been seen using an immediately loaded intramedullary-rod model in the canine. Most important were the rapid development of the interfacial shear strength and the observations that bone proliferates on the hydroxylapatite coating as well as on the wall of the reamed host bone. This indicates that the hydroxylapatite coating acts as a substrate for deposition of osseous tissue. Similar effects were seen in a canine hip replacement model. The uncoated titanium was not surrounded by bone after ten weeks; rather, fibrous tissue was found immediately adjacent to the metallic device. Immediate loading did not allow an intimate bone-metal interface to form.

Historically, many materials systems used in orthopaedics first emerged in the dental and oral surgical arenas. Hydroxylapatite-coated titanium has been used for subperiosteal and endosteal dental implants when compared with uncoated varieties.

The implications of these findings are:
1. the potential for reduced time to healing
2. a device that is less susceptible to fixation failure

The observed “biointegration” that occurs at the hydroxylapatite-bone interface as bone preferentially deposits on two surfaces presents the potential for greater initial stability, leading to longer service life. The establishment of bone directly on the implant surface with no intervening fibrous tissue can result in more efficient stress transfer through the device to bone. The ability to obtain an intraoperative interference fit is not always present in revision total joint surgery. Thus, a hydroxylapatite-coated device might not only provide a new mechanism for retention, but compensate for the imprecise fit by permitting gaps to be filled by bone.


The “bioactive” materials, primarily calcium phosphates, have provided the scientific and clinical communities concerned with hard tissue materials with substances of interest for over 15 years. Typically, when placed in hard tissue sites, the hydroxylapatite (HA) and tricalcium phosphate (TCP) types of calcium phosphate ceramics, provide osteophilic scaffolds upon which bone proliferates. This basic tissue reaction is, however, subject to short and long term modification dictated by significant or subtle differences in implant chemistry or physical form. Therefore, it is important to understand and control the material variations of the calcium phosphate system in order to generate a uniform and reproducible biological response to their implantation.
Experiential data obtained from numerous in-vivo studies has confirmed the biocompatibility, reproducibility and osteophilic nature of a series of calcium phosphate biomaterials. HA in the dense, microporous and macro-porous form has been shown to elicit the same intimate bone-implant surface characteristics as TCP at the light microscopic level, with chemical bonding demonstrated at the ultrastructural electron microscopic level between the dense HA forms and bone.

There are many ways to apply bioactive coatings to metallic substrates, but they fall into five major technique categories: oxidation, mechanical capture, dipping, plasma (flame) spraying and sputtering (vacuum deposition). Oxidation, most often associated with titanium, describes the autoformation of an oxide transition layer on the metallic structure.

Mechanical capture describes the physical entrapment of macroscopic entities (such as calcium phosphate particles) on the surface of a device. Dipping, usually associated with glass-on-metal systems, describes the coating of a metallic substrate by submergence in molten glass. Plasma (flame) spraying is the process in which fine particulates are introduced into a high speed, energized gaseous stream, melting and propelling them onto the substrate metal. Sputtering or vacuum deposition involves the removal of molecular level particles from a suitable target material by an electrical energy source, with deposition on the prepared metallic substrate. All of these but the sputtered coating are considered to be “thick” coatings (>10 microns), while vacuum deposited coatings are generally on the order of hundreds of Angstroms (tenths of microns).

Each process has its advantages and disadvantages, and is either in current use or being investigated as a coating technique for the future. Dipping, mechanical capture, oxidation and plasma spraying are techniques that have been or are being utilized, with the latter currently enjoying the most popularity. Sputtering and other vacuum deposition techniques hold much promise for the future, once various technical obstacles are overcome.

The properties of plasma sprayed calcium phosphate coatings (HA, TCP, and HA/TCP) are dictated by starting materials and by the nature of the plasma deposition process. Starting materials have an effect on the resulting coating composition, but the mechanical properties of the coating-metal system are limited by the process itself. Uniformity and reproducibility are important factors in establishing and maintaining a consistent biological profile. Tensile strengths of over 62 MPa (9,000 psi) would be rare and shear strengths of approximately 20.7 MPa (3,000 psi) would be expected. The highest density obtainable is most advantageous, with significant maintenance of mechanical and physical property integrity after in-vitro aging in simulated physiological media.

**In-vivo tests have shown various calcium phosphate coatings to be effective in increasing the interfacial attachment strength of bone to the implant, decreasing the time to attain significant levels of bony attachment, and minimizing or eliminating interfacial fibrous tissue seams.** All of these positive results are in comparison to uncoated metallic counterparts with equivalent surface textures or macroscopic features. These positive consequences have been observed in passive, mildly loaded or immediately loaded (weightbearing) animal models. The most extensive in-vivo data has been reported on HA coatings.

**Encouraging Aspects of Coated Prostheses:** The enhanced deposition reaction of bone onto to coated metallic implants is, of course, a very attractive feature of the system. Certainly, the implications of an enhanced deposition rate have far reaching consequences on the concept and prepared of “osseointegration”. Implants apparently have a **faster rate of incorporation in bone** due to the deposition of bone on two surfaces, the prepared bone site and the coated implant surface. These observations are consistent with early findings of the chemical nature of the HA-bone bone, ie., “biointegration”. Biointegration, defined as the “demonstrable, mechanically significant biochemical bonding of living bone to the surface of an implant that is independent of any interlocking mechanism and identifiable at the electron microscopic level of observation.”
Hydroxylapatite Coatings

Clinical Potential: The results of animal studies demonstrate that HA coated metal appears to be a viable alternative for biological fixation by *impacting a chemical rather than mechanical type of fixation*. The apparent mineralization directly onto the HA surface enables maximum interfacial strength to be attained at earlier time periods and increases the rate of bone adaptation to the surface of the implant. Implant fixation is positively affected by the ability to deposit osseous tissue on both the bone surface and the implant surface and may provide a mechanism for accelerated tissue adaptation leading to greater longevity for orthopaedic devices.

Chemical bonding can expand the use of metallic implants by creating a perfect post-implantation implant placement site. Properly designed, this phenomenon will allow faster restoration of the submerged implant bodies when compared to metallic devices. Additionally, surface modifications to conventional metallic devices represent a refinement of contemporary interpretations of "osseointegration."

Reduction or elimination of fibrous tissue formation, another benefit of dual-surface bony deposition, will make the short term response to oral implants more predictable. The reasons for first year failures shared by most current designs are installation variability and initial tissue response. The implications of bioactive coatings on initial stability of blade-type dental implant are obvious. Dual-surface deposition could enhance the initial stability of properly designed devices, bony adaptation can provide the support that fibrous or fibre-osseous mechanisms cannot.

The possibility exists for increased long term implant success. Often forgotten and dismissed after several years of implant stability, however, is the potential for long term failure of the device. The reasons for confidence are that the implant is seen stable, osseointegration has apparently been established, and the device appears to be functioning. But two contributing reasons for initial tooth loss may be overlooked: the first is the continued natural progression of the patient’s bony architecture, and the second is the frequent history of poor oral hygiene exhibited by most dental implant candidates.

Hydroxylapatite coatings may be tolerant of over ten years of natural bony changes surrounding the device and provide a bone maintenance system around the superior aspect of the implant. *Additionally, a coating of HA may prevent or reduce the incidence of epithelial downgrowth*, as it apparently has done, initially, for coated implants and HA particles which are properly placed in periodontal lesions. Such coatings and, in some cases, concurrent placement with particulate HA will provide equivalently high levels of success for wide and medium ridges. Success of implants placed in the narrower ridges can only be increased by a mechanism that enhances the bone deposition rate. Recommendations have been made against attaching "osseointegrated" implants to adjacent natural teeth, for fear that natural tooth functions would be compromised and lead to failure. The promotion of biointegration and subsequent bone remodelling may allow this recommendation to change.

Most encouraging is the efficacy of coated materials systems in reported animal evaluations and clinical experiences in oral surgical and orthopaedic indicators. While the early response enhancement of the materials system has been attractive, the coatings have been utilized in the oral environment for non-structural applications, only. Increasing the attachment strength and modifying the chemical properties of coatings promise for permitting dependence in structural situations. Longer term experiments and clinical experience are required for this to come to pass.

Future Applications: Perhaps the most exciting aspect of the developments in surface science and coatings to date is the promise for even greater advances for the future. Aside from analytical and surface science techniques to better study and understand surface, interfacial and coating structures, progress will occur in coating design, placement and composition. This will permit tailoring of implant devices to control the biological response, and thus the overall efficiency of the implant.
Conclusions: The bioactive coatings available today represent an incremental increase from metals materials technology and an interim step towards more tolerable biologically active systems. Coatings available today are based on favorable results obtained in laboratory, animal and clinical evaluations. Several coatings of calcium phosphate biomaterials represent the first efforts to control and direct the biological response on the surface of metallic implants. While the results are encouraging to date and directions for future materials developments are charted, caution must be exercised when utilizing the current available systems, as it can be susceptible to inconsistency, damage or misuse. Clearly, however, it is apparent that surface coatings will be used to enhance and control the biological response of bone to implanted metallic devices.

BIOACTIVE SURFACE COATINGS: FOR HARD TISSUE BIOMATERIALS, John F. Kay, Bio-Interfaces, Inc.; San Diego, California

Introduction: Affixation of hard tissue augmentation or replacement devices has made incremental progress through the ages by utilizing advances in materials science. The basic concept of mechanical attachment has been known for centuries. The last two decades have seen focus on ceramic materials change from "bio-inert" (eliciting little or no active tissue interfacial response) to "bio-active" (eliciting normal and hard tissue interfacial response). The search continues for materials that enhance the normal response, but this concept has yet to be demonstrated as being possible.

Physical Characteristics: Hydroxylapatite coatings are 50 to 75 microns in thickness, identified by power X-ray diffraction and tested using ASTM techniques for mechanical properties. As coated tensile strengths of 6,000 psi (minimum) and shear strengths of 2,500 psi (minimum) are indicative of these ceramic coatings.

Biological Profile: Hydroxylapatite ("HA") coatings enhance, in a way, the bony response by providing an osteophilic substrate on which bone proliferates concurrent with normal growth on the prepared bone site surface. This response is novel in that bone normally grows from the prepared bone site and elaborates toward the metallic device, thus, one reason for the precision fit requirement for "press fit" devices, Tricalcium phosphate ("TCP") coatings may initially serve such a role, but the result of fairly rapid bioresorption on device stability is not yet known. Clinical use of HA coatings in the dental and orthopaedic areas, albeit early, is positive and consistent with trends observed in animal evaluations.

Clinical Usage: Successful utilization of calcium phosphate coatings requires a knowledge of the material, the biological profile and biomechanical considerations. The consequences of any coating failure, however defined, can be minimal if all three areas are addressed.

Three coatings must be thin (100 microns) and can be utilized to create an ideal implant site post-implantation through the preferential deposition reaction. An efficient bone architecture for stress transmission is thereby established, with an ordered cancellous structure providing the load bearing capability. Tailoring of the biological response around an implant can be accomplished by manipulation of physical, chemical and mechanical characteristics of thin calcium phosphate ceramic coatings.

CALCIUM PHOSPHATE CERAMICS: WHAT ARE THEY?, John F. Kay, Harrington Arthritis Research Center; Phoenix, Arizona

Biological Profiles: Dense hydroxylapatite has been the subject of laboratory investigations for over a decade, when early in-vivo experiments demonstrated it to be a stable, non-bioresorbable material that provided a scaffold for bony proliferation. When stressed to fracture, the bone-HA composite thus formed typically
in the bone, leaving remnants of bone covering the HA surface and providing evidence for a tenacious attachment shown to be “chemical” in nature, as opposed to a physical adaption of bone to the surface of other bioinert ceramics such as alumina or pyrolytic carbon. There is a deposition of bone mineral on the surface of HA that give rise to the great strength of the HA-bone bond. Dense HA is stable, not participating in the remodelling of bone that may be occurring immediately adjacent to it and is not vascularized in-vivo. Fibrous tissue is seen on the HA surface if significant motion does not allow initial stabilization or if the ceramic is intentionally placed in soft tissue; it is not osteogenic in that bone will not be formed on its surface when placed in other than bony sites. While limited in practical application by its brittle nature, the bone-bonding characteristics of HA may be exploited in the form of coatings on metallic appliances. These coatings have the potential of creating a faster and stronger attachment of bone to metallic orthopaedic devices.

DESIGNING TO COUNTERACT THE EFFECTS OF INITIAL DEVICE INSTABILITY: MATERIALS AND ENGINEERING, John F. Kay, PhD, Bio-Interfaces, Inc.; San Diego, California

Implants for hard tissue replacement have evolved over the last few decades, but a critical assessment of their design reveals that most dental implants and most orthopaedic appliances for any given indication are basically similar in design to their commercial competitors. Some unique features are contained in the outer 0.7mm, but shadow pictures of the devices could almost be superimposed upon one another. Near-optimal designs have evolved for the materials systems commonly in use. The fight to minimize initial instability of implants, which leads to failure, has caused certain attachment mechanisms to emerge as acceptable, based upon research that indicates firm fixation in bone has resulted in longer average implant lifetime. The problem of initial stabilization is one of materials and design, both of which are necessary for a successful implant system. The nonmetallic calcium phosphate glass and ceramics technology available today provides materials that may counteract the effects of initial device instability by not relying on mechanical means of retention, alone, but chemical as well.

Mechanical Interlocks: The argument for mechanical interlocking is based on sound reasoning, post-operative assessment of clinical success and animal research suggesting that bone will grow up to and appose an implant surface. To date, mechanical interlocking is the most effective manner of implant fixation. The fixation of all metallic and ceramic implants used in dentistry and orthopaedics depends upon the establishment of a mechanical interlock.

The ancients used screws for dental implants and a 1938 patent attests to the fact that the screw-in dental implants of today utilize an old method of attaining immediate stability. Until recently, nothing new has emerged as a viable alternative for fixing metallic devices.

Bony adaptation to vents, screw threads or surface pores has also been used as a fixation mechanism for some ceramic materials. Such macroscopic surfaces features are needed on one implant surface only; i.e., they need not be deeper than a small surface layer in depth to produce mechanical attachment. Features such as threads cut into bone and force immediate interfacial intimacy.

However, threads, per use, may not be required. A proper interference fit provides the immediate interfacial intimacy necessary for good initial and potential long term stability, provided that the device design and loading environment will allow bony adaptation. With no “glue” or chemical fixation, new bone must grow up to the implant surface to secure it. However, this takes time. The effect of simple grit blast surface roughening on a variety of materials, including titanium and alumina, was a consistent ability to obtain direct bone apposition when compared to their smooth surfaced counterparts.
The bioactive material experiencing the widest clinical usage is hydroxylapatite. The reason for this popularity is a demonstrated, strong, biological bond at the bone-implant interface. This is due to the chemical similarity between bone mineral and the synthetic HA ceramic. The biological bond is a consequence of a normal healing sequence around the dense HA ceramic and has been shown to be stronger than the bone itself, with fracture occurring in the surrounding bone when stressed to failure.

Hydroxylapatite coatings have been applied to porous-suraced implants, demonstrating an early enhancement of bony adaption and interfacial strength, providing increased stability at short times. Immediately loaded canine hip replacements with HA coated porous attachment areas show the same histological enhancement. In a quantitatively evaluated, immediately loaded IM rod model, HA coatings provided an over four fold increase in interfacial shear strength when compared to uncoated rods placed in the identical fashion. Perhaps the most important advantage of calcium phosphate coatings is not the increase in interfacial shear strength, but the increase in the speed of adaption of bone, manifested as the increase in shear strength. The coatings apparently act as a substrate for bony proliferation consistent with dense HA experience, inhibiting formation of fibrous tissue at the implant surface.

The challenge of the 1990's is to take what has been developed in the materials and chemistry laboratories and use them to design implants. the attractive properties of surface-active materials far outweigh the undesirable properties. It is possible that the effects of initial instability can be effectively counteracted with prudent engineering using some exciting materials systems available today. Calcium phosphate surfaces applied to metallic devices can decrease initial post-implantation instability and, thus, may provide devices that are not as susceptible to the inevitable installation variability associated with their implantations.

HYDROXYLAPATITE COATINGS, John F. Kay, Harrington Arthritis Research Center; Phoenix, Arizona

A composite of bioactive HA ceramic coating on strong, manufacturable titanium could widen the clinical use possibilities for both materials, possibly aiding in the fixation of hard tissue prosthetic devices. A ceramic HA coating was applied to prepared surfaces of titanium using a modified plasma spray deposition apparatus. Mechanical tests of the coating indicate a 17.5 MPa tensile strength and 17 MPa shear strength is maintained after 120 days aging in agitated Ringer’s solution of 37 C. The addition of macroscopic surface texture in the form of grooves doubles the shear strength due to a mechanical advantage and shielding of the coating from pure shear forces.

Smooth HA coated titanium implants were compared to grit blasted titanium implants to see the effect of the coating loaded in pure shear. At all time periods from 3 to 32 weeks, the HA coated implants were significantly stronger than their uncoated titanium counterparts. Significant interfacial shear strength was established as early as 3 weeks with the HA coated samples, which increased to a maximum value of 7 MPa by 5 weeks postossseous deposition around the entire periphery of the HA coated implants, even in places such as the center of the medullary canal. The deposition of new bone on the surface of the HA coating and on the fresh bone surface of the site preparation explains early establishment of significant interfacial shear strength and the high shear strength at maturity since intervening fibrous tissue was never observed.

The elaboration of osseous tissue from two surfaces to fill the small defect between the implant and the bone to fix the device was contrasted with the response to titanium, where elaboration of bone was only observed from
the prepared bone surface, preceding towards the metal surface. Occasionally, bone could be seen in direct contact with the titanium surface but more frequently, a thin 2 to 3 cell layer thick fibrous tissue seam separated the actual metal surface from the advancing bone. For the titanium surface implants, failure always occurred at the metal interface while for the HA coated implants, failure was observed in the bone in the early time periods and later moved to a failure within the coating and/or at the HA metal substrate, an indication of a strong bond of bone to hydroxylapatite.

Preliminary results of the interfacial pushout tests indicate that at 5 weeks, the **HA coated titanium is 8.4 times stronger than the uncoated grit blasted titanium and at 10 weeks**, the HA coated titanium reaches a level of 4.3 MPa, 4.5 times greater than that for titanium. Ground section histological analysis indicates a deposition of osseous tissue on the surface of the HA, where no such deposition is observed for titanium. The titanium is surrounded by fibrous tissue, the effect of the immediately loaded model and the inability of the rod to be firmly anchored by bony apposition due to the stresses of motion. The HA, on the other hand, was effective in providing a scaffold for bony proliferation on the surface of the implant and on the prepared bone site, again giving rise to the increase in interfacial shear strength and the more rapid establishment of fixation.


The object of this study was to evaluate hydroxylapatite coated surgical alloys for structural, mechanical, and physical properties, as a possible alternative. HA coated smooth titanium (Ti) alloy, cobalt-chrome-molybdenum (CoCrMo) alloy, and hydroxylapatite coated porous titanium were evaluated. These coatings were applied using a modified plasma spray process and analyzed for physical and chemical characteristics using scanning electron microscopy, powder X-ray diffraction, pycnometer density determination, wet chemical analysis, atomic absorption spectroscopy, and dissolution kinetics.

HA coated porous titanium substrates have demonstrated interfacial shear strengths of 34 MPa with no apparent degradation associated with aging. In tension, approximately 65% of the 40 MPa as coated strength is retained after 60 days aging in Ringer’s solution.

The results of the materials characterizations performed indicate hydroxylapatite coated metal may have attractive properties for applications in orthopaedics. Adequate interfacial strengths have been maintained for extended aging periods and a biological bond between bone and the coating is anticipated in vivo due to the demonstrated chemical and physical equivalency of the coating to dense non-resorbable HA ceramic used in human clinical applications for nearly a decade.


Hydroxylapatite (HA) has been shown to chemically bond directly to bone through a biological “apatite”. This property may be advantageous for dental implant stability and maintenance. This study evaluates the bone interface reaction of HA coated and non-coated titanium dental implants in dogs. Clinical evaluation demonstrated zero mobility and periodontal pockets less than 3 mm. Two implants were loose and lost initially from oversizing the bone sit. The gingival reaction to the HA surface was not significantly different to the smooth titanium interface. Calculus formation was minimal.
50% of the grit-surfaced implants were adherent, whereas 100% of the HA coated implants were adherent and not able to be removed from the bone. These implants were removed only after decalcification. Calcified and decalcified histological sections revealed similar findings. The non-coated implant-bone interface was completely lined with fibrous tissue. The thickness of this fibrous tissue was greater in the smooth surfaced implants compared to the grit surfaces implants. Very few areas of direct bone-titanium contact were found. The HA-coated implants demonstrated an intimate bone-implant interface without intervening fibrous tissue. The early (1 month) specimens were not completely encased by bone. Bony trabeculae extended to the implant, with these trabecular attachments to the implant separated from each other by cancellous marrow elements. By four months, the bone-implant interface was more consolidated with the formation of a layer of lamellar bone.

SEM evaluation revealed the polished and grit surfaced implants enjoyed few areas of actual bony apposition with the majority of tissue contact being a fibrous nature with direct attachment of fibroblasts to the titanium surfaces. However, the HA-coated implants were observed to have bony attachment to the implant surface. This bony attachment extended from the apex to the coronal aspect of the implant and was evident as early as one month in vivo. There was no evidence of resorption of the HA coating.

The HA coating of titanium resulted in a bone-implant interface without an intervening fibrous tissue. This chemical bonding of bone to HA coated endosseous dental implants may provide an increased stability and retention over polished and grit surfaced cylindrical titanium dental implants.

THREE YEAR CLINICAL RESULTS WITH HA COATED DENTAL IMPLANTS, J.N. Kent, M.S. Block, D.S. Misiek, Proc. World Biomaterials Congress, April 1988, Kyoto, Japan (Sub. for Presen)

This study reports three year clinical follow up of HA coated dental implants in patients. Four hundred fifty seven implants were placed in 30 patients for prosthetic restoration, including fixed and removable prosthesis. Of particular interest were implants which were “loose” in the socket at surgery, yet after the healing period, all were biontegrated. This finding was attributed to the early healing sequelae observed with HA coated implants. Clinical biointegration was noted as early as eight weeks. The HA coating also seemed to help in those patients who may have been suboptimal candidates for non HA coated systems. Cumulative success rate found in this study was 97.4%, interval success rate was 95.5%.

HYDROXYLAPATITE COATING, Jack Krauser, DMD, Symposium on hydroxyapatite coatings, 1995

The scanning electron microscope at 9,000 power shows biologic apatite crystals bridging from bone to the implant surface resulting in more rigid fixation in bone than with titanium implants. HA-coated implants seem to work well in Type 3 and Type 4 spongy bone.

Studies have shown that there is bone loss in IMZ and Branemark systems, extending to the plasma-sprayed titanium surface in the IMZ system and to the first thread in the Branemark system. When implants are coated to the top with HA, there is no automatic loss of bone in the crestal area under loading, as with systems with polished necks.

Resorbability of HA coatings can be a factor of a number of variables a small percentage of a resorbable phase of HA present during coating, increased crystallinity and the presence microcracks in the surface coating.
Hydroxylapatite Coatings studied the efficacy of HA versus grit-blasted titanium, with and without PTFE membranes and concluded that the membranes plus HA coatings healed better than membranes with the grit-blasted titanium surfaces. Another study, at Louisiana State University in dogs, tested collagen barriers and found that HA-coated implant surfaces healed better than titanium ones in dehiscence defects. Peri-implantitis around HA implants is a different clinical entity than when it appears around titanium or titanium alloy-surfaced implants. In a five-to six-year post-implant placement study by the author, he concluded that the mandibular posterior region had the greatest percentage of failures.

BIOINTEGRATION: HYDROXYLAPATITE COATED METAL DENTAL IMPLANTS, J.T. Krauser, Florida Dental Journal, Fall, 1987

This article overviews the advances in dental implantology and presents case reports of hydroxylapatite (HA) coated endosseous implants. In all case reports there was no note of crestal bone loss as seen with other uncoated titanium implant systems. The author states that perhaps the use of HA coated metal endosseous implants is not only yielding a stronger mechano-chemical bond, but it also negates the surgical trauma and biological insults at time of placement. The biological factors of the implant body and the versatility of the prosthetic components make the methodology ideal for clinical use. Machined titanium implants demonstrated a thick fibrous encapsulation with fibres parallel to the long axis of the implant in nonfunctional orientation and were easily removed with a curette. The grit surfaced implants demonstrated a thinner encapsulation. All HA coated implants were histologically biointegrated at earlier time frames than the noncoated implants. The HA coated implants were covered with a thick dense layer of lamellar bone on most of their surfaces. No evidence of resorption of the HA was evident in any section. The coronal growth of the bone on the HA surface with new gingival fibres inserting perpendicularly into the newly formed bone.


For conditions of early implant loading, a porous-surfaced implant appears to elicit a significantly different response than a threaded implant design. Such implants appear to be at least as successful as threaded designs despite the much simpler procedure used for placement of porous coated implants. Further, the results of these studies suggest that porous coated implants could be made shorter than threaded implants and still develop equivalent fixation. This design is expected to perform better in situations where some micromovement of the implant relative to the host bone occurs (as for example first extraction site implants).

“Hydroxylapatite coatings have shown promise due to the enhanced integration of osseous enhanced tissue to coated implant surfaces. When compared with healing around commercially pure or titanium alloy implant surfaces, hydroxylapatite-coated implants appear to be superior in sites which are compromised in either quantity or quality of bone. After 8 years of clinical utilization, the hydroxylapatite-coated implant surface has not been shown to be predisposed to increased long-term failure.

“In Type III and Type IV quality bone there appears to be a preference for HA-coated implants, regardless of whether each clinician advocates or does not advocate comparable use in Types I and II.”

The purpose of this study was to assess the effect of a hydroxylapatite coating on the interfacial shear strength between metallic intermedullary rod implants and bone in an immediately weight bearing animal model.

Twelve adult mongrel dogs (approx. 20 Kg.) were used in this study. Two intermedullary varieties were used: Ti6A14V with a grit blasted surface finish and Ti6A14V coated with hydroxylapatite. Implants were 10cm in length and either 9 or 10mm in diameter.

The femoral canal was precision reamed to a final diameter of either 9 or 10mm, the periosteum was divided, and a midshaft osteotomy performed. An intermedullary implant was inserted as a press fit and layered closure effected. The animals were allowed unrestricted motion post implantation. At sacrifice after 5 and 10 weeks, intact femurs were excised, stripped of soft tissue, and divided into sections for mechanical and histological evaluation.

Histologically, the HA coated implants were surrounded by a thick bony proliferation with no evidence of a fibrous tissue seam. Uncoated implants were surrounded by a thin fibrous seam several cell layers thick.

Mean values for five and ten week pushout tests were 20-25 times greater for the HA coated implants versus the uncoated controls. The results of this study indicate HA coatings can enhance implant fixation in a quantitatively evaluated weight bearing model. Despite the fact that post-op radiographs showed that precision placement of rods was not always obtained, the increase in shear strength was achieved consistently. Thus, metal implants with hydroxylapatite coatings may not be as susceptible to the installation variables which have adversely affected other press fit implants.

WHAT IS OSSEOINTEGRATION?, R.M. Meffert, M.S. Block, J.N. Kent, Int’l J. of Periodontics & Restorative Dentistry

This article discusses implant materials and systems in regard to true chemical bonding to bone. Grit blasted titanium, as machined, or smooth titanium and hydroxylapatite (HA) coated implant designs were observed for interface characteristics and hard and soft tissue responses. Implants were placed at crestal bone level and pregingival. Periodontal examination was made to determine pocketing and/or saucerization. As machined titanium implants demonstrated a thick fibrous encapsulation with fibres parallel to the long axis of the implant in nonfunctional orientation and were easily removed with a curette. The grit surfaced implants demonstrated a thinner encapsulation. All HA coated implants were histologically biointegrated at earlier time frames than the noncoated implants. The HA coated implants were covered with a thick dense layer of lamellar bone on most of their surfaces. No evidence of resorption of the HA was evident in any section. The coronal growth of the bone on the HA surface with new gingival fibres inserting perpendicularly into the newly formed bone.


Samples from intraosseous dental implants were removed from patients for mechanical failures with implantation times up to 8 years. No failures had arisen from problems at the interface between the hydroxylapatite coating and the bone.

The **HA coating may have a clear advantage for use in the maxilla or in other areas of poor quality bone, in more complex surgical situations such as immediate implant placement, expansion of the residual ridge or sinus elevation.**

PERFORMANCE OF MAXILLARY HA-COATED AND NON-COATED IMPLANTS AT SECOND STAGE SURGERY

The maxillary “common odds-ratio” determination indicated that the **odds of a failure with a non-coated implant is 4.16 times greater than with a HA-coated implant**, disregarding the bone


The interface attachment characteristics and histologic response to hydroxylapatite (HA) coated metallic implants were examined. Implant materials included Ti-6A1-4V and Co-Cr-Mo alloy; both uncoated and HA-coated dense, porous, and macrotextured surfaces were evaluated. The HA-coated implants exhibited greater attachment strengths and maximum strengths occurred at earlier time periods when compared to the uncoated implants. Further the HA-coated textured implants exhibited attachment strengths approaching that of the long-term porous implants, and therefore the HA-coated metal appears to provide an alternative to mechanical biologic fixation (porous ingrowth).


The objective of this study was to determine the effect of hydroxylapatite (HA) ceramic coatings on the ultimate interface shear strength, the rate of development of attachment strength and the degree of bone ingrowth or apposition to various implant surfaces. In addition an evaluation of HA-coated hip endoprostheses in the canine model was also undertaken. The systems evaluated included: Ti-6A1-4V with 0.5mm porous CP titanium coating; CP titanium textured with annular grooves; CP titanium textured with holes and HA coated; dense CP titanium; Ti-6A1-4V textured with a single layer porous coating; and dense Co-Cr-Mo alloy. All systems were evaluated with and without an HA coating.

The HA coating was a plasma sprayed 75 micron thick dense layer with purity and composition confirmed by X-ray diffraction and wet chemical analysis. The TC implants were evaluated by surgical placement in the femurs of 36 adult mongrel dogs. The development of the maximum interface strength was twice as long for the non-HA coated specimens, 3-6 weeks for the HA-coated porous system versus 6-12 weeks for the uncoated system.

The dense titanium and Co-Cr-Mo systems with **HA coatings showed a 4-7 fold increase in interface attachment strength** when compared to the uncoated dense systems. In histologic sections the HA-coated systems exhibited an increase in bone ingrowth, apposition and degree of mineralization at early time periods compared to the uncoated systems. At later time periods the systems became equivalent. In the HA-coated systems bone appeared to be directly mineralized to the implant surfaces. On the HA coated implant surface
in the intramedullary area, a thin osseous layer was present which was not observed in the uncoated systems. Measurements of HA coatings showed the thicknesses remained constant at all time periods.

The **HA-coated textured implants exhibited bony deposition on all HA coated areas as early as 3 weeks post-implantation**. At all time periods, an increased amount of bone was present in the HA coated implant, and appeared better organized and more highly mineralized. **At up to 52 weeks in function there was no evidence of any separation of the HA coating from the Ti-6Al-4V alloy substrate.**


The objective of this study was to ascertain the biological response to load bearing hydroxylapatite coated and uncoated porous titanium implants placed in the hips of adult mongrel dogs. The HA coating was applied using a plasma spray process. The purity and composition of the resulting HA coating was confirmed by X-ray diffraction and wet chemical analysis. These coatings have been shown to be identical to the currently used solid particulate hydroxylapatite material used in oral and maxillofacial surgery applications.

**An increased amount of bone ingrowth was present earlier in the HA coated system as compared to the non HA coated system.** This bone also appeared to be better organized and had a higher degree of mineralization. In the non-porous areas along the distal stem of both systems, a fibrous tissue layer with collagen bundles oriented parallel to the implant surface was observed. The thickness of this interface, although increasing with time in the early implantation periods, appeared to be well stabilized by 24 weeks.

Histologically, the HA coated implants were surrounded by a thick bony proliferation with no evidence of a fibrous tissue seam. Uncoated implants were surrounded by a thin fibrous seam several cell layers thick.


A mechanical and histological evaluation of uncoated and hydroxylapatite coated titanium implant materials was performed. Cylindrical implants of uncoated commercially pure (CP) titanium and hydroxylapatite-coated Ti-6Al-4V alloy were studied using a transcotical model, with implants evaluated after periods of 3, 5, 10 and 32 weeks. All implants had a surface macrotexture consisting of a series of semi-circular annual grooves, approximately 750 microns in maximum depth. The attachment characteristics of interface shear stiffness and interface shear strength were determined by mechanical push-out testing. The results of this study may be summarized as follows:

1. Mechanical push-out testing results indicated that the **hydroxylapatite coated implants exhibited significantly greater values of maximum interface shear strength** than the uncoated implants after 3, 5 and 10 weeks.

2. Interface shear stiffness was also **significantly greater after the 3, 5 and 10-weeks** time periods for the hydroxylapatite coated implants as compared to the uncoated implants.

3. Histological sections from the hydroxylapatite coated implants demonstrated **mineralization of bone directly onto the hydroxylapatite surface.** In no case was a fibrous tissue layer interposed between the hydroxylapatite
4. Histological sections also revealed the presence of an osteoid layer covering all hydroxylapatite osteoid surfaces after 3 weeks implantation. This layer appeared completely mineralization by 10 weeks postimplantation.

5. Sections from the uncoated CP titanium implants showed a predominately fibrous tissue interface.

6. An appropriate surface macrotexture, such as significantly enhance implant fixation by direct bone ingrowth or apposition by providing a mechanism for establishing considerable attachment strength shortly after implantation.

7. The use of hydroxylapatite coatings can significantly enhance implant fixation by direct bone ingrowth or apposition by providing a mechanism for establishing considerable attachment strength shortly after implantation.

HA AS BONE REPLACEMENT GRAFT, Raymond Yukna, DDS, MS, Symposium on HA coated implants, 1995

In an implant capacity, HA can encourage a direct disposition of bone on its crystalline surface, the newly forming osteoid actually chemically bonding to HA. The junction of bone and ceramic appears stronger than the bone itself. This may be important in implant dentistry. It has even been shown that with an HA surface on a dental implant, there is potential for bone to grow in a coronal direction on the implant. Without inflammation and low pH levels, there is no natural phenomenon for dissolution to take place in normal-physiologic function. There is an exchange of ions at its interface with bone, but this has a stabilizing effect.

The biologic advantages of an HA coating in this less dense bone may foster better and more complete bone-to-HA contact. Overall there are advantages to HA-coated implants: 1) faster bone response (histologic), 2) HA may stabilize the bone and make it more resistant to breakdown; 3) HA has a stronger bond to bone than titanium does; 4) an HA coating may provide more flexibility for surgical inaccuracies.

When placing implants into immediate extraction sockets, one needs to go beyond the apical extent of the extraction socket and, wherever possible, engage lateral walls. Since normal healing will resorb some of the bone, place the implant a little deeper into the socket. If there is a gap between the implant and the lateral socket walls, HA-coated implants will bridge this gap better than non-HA coated implants.

HA-COATED ROOT FORM IMPLANTS - IS THERE CAUSE FOR CONCERN?, M.H.Zablotsy, Dental Implantology Update, May 1993, Vol.4, No.5, pg.37

Hydroxylapatite coatings have shown promise due to the enhanced integration of osseous tissues to coated surfaces. When compared to healing around commercially pure or titanium alloy implant surfaces, hydroxylapatite-coated implants appear to be superior in sites which are compromised in either quantity or quality of bone.

After 8 years of clinical utilization, the hydroxylapatite-coated implant surface has not been shown to be predisposed to increased long-term failure.