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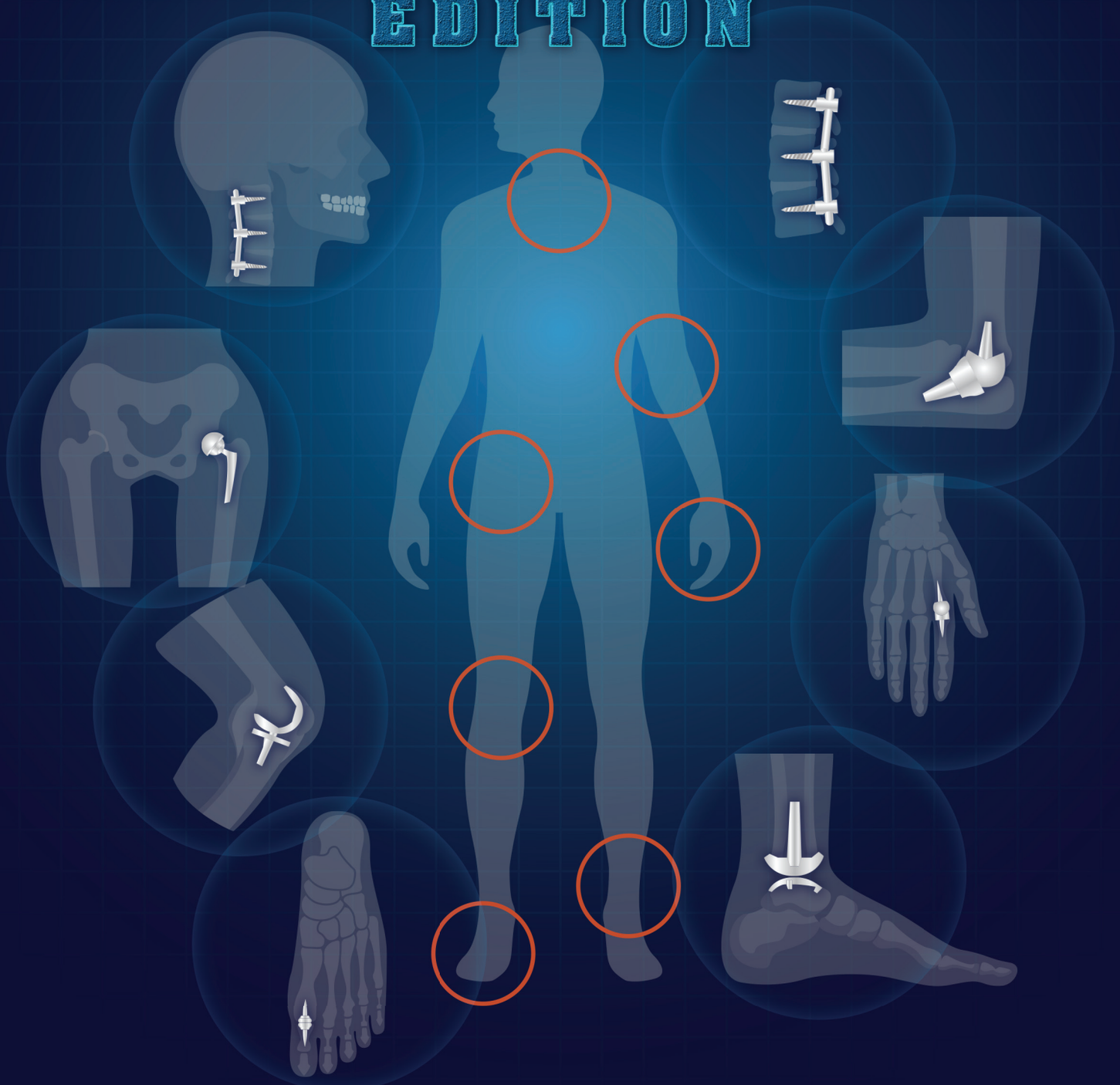

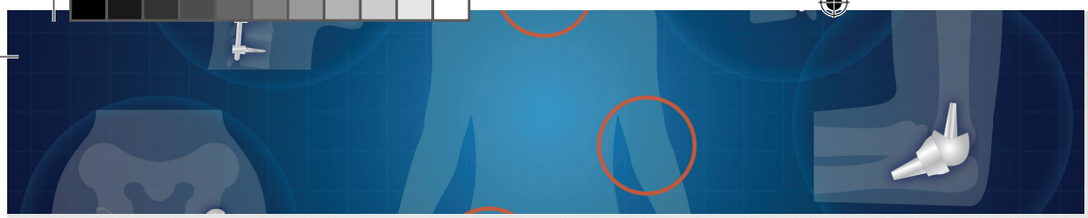

Titanium, Zirconia Vie for Dental Implant Applications; Improvements from C-ECAP Technology Under Review

The global market for titanium dental implants is expected to see solid annual growth through the near term, following suit with projections for titanium medical implants (hips, knees, etc.), according to findings by several market research organizations. Some research groups track zirconia as a competing material technology for this medical application. However, it's unclear if the intense focus on the ongoing Covid-19 pandemic will affect the pace of dental implants during the next 12 to 18 months.

One titanium material technology under review for dental implants, and possibly other market applications, is known as equal-channel angular pressing (ECAP). An online abstract (https://link.springer.com/article/10.1023/A:1017932417043) described ECAP as "a processing method in which a metal is subjected to an intense plastic straining through simple shear without any corresponding change in the cross-sectional dimensions of the sample. This procedure may be used to introduce an ultra-fine grain size into polycrystalline materials." Fort Wayne Metals is one company exploring this ECAP technology (see text below).

Aside from applications for dental implants, titanium is expected to achieve steady, near-term growth as a material of choice for cranial implant surgical procedures (see sidebar)

Grand View Research, based in San Francisco and India, forecasts that the global dental implants market, estimated to be $4.6 billion in 2019, is expected to register a compound annual growth rate (CAGR) of 9 percent through the year 2027. Market Research Engine, Solapur, India, estimated that the global dental implant market is expected to exceed $6.5 billion by 2024, with a CAGR of 7.9 percent. Both groups posted their market forecasts earlier this year. Other organizations, such as Technavio Research, 360 Research Reports, Mordor Intelligence, Transparency Market Research, and Research and Markets, all generated similar projections.

The reports cited statistical information gathered from a variety of sources such as the American Dental Association, the American Academy of Implant Dentistry, the National Health and Nutrition Examination Survey, the World Health Organization, and the European Commission. They also identified companies such as BioHorizons IPH, Inc.; Nobel Biocare Services AG; Zimmer Biomet Holdings Inc.; Institut Straumann AG; DENTSPLY Sirona; and KYOCERA Medical Corp. as being key market producers of dental implants.

According to the findings issued in the report by Grand View Research, titanium held the largest market share in 2019, "owing to the wide use of dental implants made up of titanium. The biocompatible nature of the pure form of titanium is the main benefit of its use. The zirconia segment is anticipated to be the fastest-growing product segment over the forecast period. Titanium implants can be made as one-piece or two-piece systems, whereas, zirconia implants are made as one-piece systems. Two-piece implants offer better features, such as they can be used to support overdentures. Implants are manufactured in different sizes (length and width), which enables the choice of implants as per patients' bone size." Separately, Markets and Research reported that, comparing the two dominant metals, "zirconia implants are anticipated to witness a lucrative growth rate over the forecast period due to better flexural strength, improved aesthetic appearance, and less corrosiveness as compared to titanium."

Much like the widespread number of surgeries for medical implants, the forecasts for the growing number of dental implants pointed to increasing demand for the aging Baby Boomer population. Outlining the estimated consumer market for dental implants, Grand View Research indicated that 10 million people are injured or disabled due to road accidents every year, while "over 15 million people in the United States undergo bridge and crown replacements for missing teeth every year, thus facilitating the demand for dental implants. Dental implants…are considered as the only restorative technique that preserves and stimulates natural bone and also act as a stable support for prosthetics (dentures). Moreover, dental implants improve physical appearance of a person and provide comfort and convenience, unlike removable dentures."

Titanium, Zirconia Vie for Dental Implant Applications; Improvements from C-ECAP Technology Under Review *(continued)*

A recent study issued by Fort Wayne Metals underlined the competitive market demand for titanium dental implants with improved strength. "The initial approach of using alloyed titanium has drawn some critical attention as some of the added elements are known to potentially cause allergies or other health issues, so some have shifted their focus on altering the grain structure of the material to achieve desirable characteristics," the company's study stated. As a result, Fort Wayne Metals' commercially pure titanium known as 4TiTUDE® (introduced in 2012) "made initial gains in demonstrating strengths comparable to cold worked Ti-6Al-4V."

Fort Wayne Metals is developing its next-generation "Continuous Equal Channel Angular Pressing" (C-ECAP) material technology, which it said would offer even greater strength and fatigue strength "while also achieving ultra-fine grains which initial studies have demonstrated to promote increased cell proliferation. The combination of purity and strength gives the flexibility to design smaller implants and maximize osseointegration" (the integration of living bone and an artificial implant). The company explained that ultra-fine grain (UFG) materials manufactured through severe plastic deformation (SPD) techniques have shown promise in titanium, on a small scale, since the early 1990s. "While there have been demonstrated increases in mechanical properties in the laboratory, translating (the enhanced mechanical properties) to commercial scale production is a barrier that must be overcome. Fort Wayne Metals seeks to overcome this barrier through focused investment in (C-ECAP) technology. Starting with commercially pure titanium Grade 4 and expanding into other titanium alloys, commercial production of UFG material to serve dental, medical and other industries will soon be a reality."

The company acknowledged that "while implementation of this advanced processing technique has its challenges, Fort Wayne Metals has leveraged its 50-year history of metals manufacturing and formed key partnerships with experts in the UFG field. Initial developments in CP Ti Gr 4 promise a repeatable, scalable process for manufacturing titanium rods with higher strength, fatigue, and osseointegration." The company noted that "we do not have a set date for commercialization or finalized trade name at this time. We are close, but have some final pieces to get into place before committing to a timeframe."

Headquartered in its namesake city in Indiana, Fort Wayne Metals (website: www.fwmetals.com) works with a wide range of materials from stainless steel and Cobalt-Chrome to Titanium and Nitinol. The company produces titanium wire,

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Titanium Remains a Material of Choice For Cranial Implant Surgical Procedures

The global market for cranial medical implants is forecasted to reach around $1.4 billion by the year 2026, with a CAGR of 6.4 percent, according to two studies posted online by Acumen Research and Consulting, and Transparency Market Research, two market research firms based in Pune, India. These cranial implants utilize titanium mesh and pins and other metals, ceramics, and polymers as materials.

A separate market research report posted by ReportLinker, Lyon, France, explained that cranioplasty "is a neurosurgical procedure involving the repair of a cranial defect or deformation caused due to trauma, neurosurgical procedures, tumors, and infections. Value-added features offered in cranial implants are prompting medical professionals worldwide to adopt technological advancement-aided cranial implantation." ReportLinker identified that the value-added features and technological advancements include additive manufacturing and CAD/CAM modeling, which can produce customized cranial implants for individual patients.

Acumen Research and Consulting, in its market forecast, reported that titanium Grade 5 is often a material of choice for cranial surgical procedures. "The accessibility and long-haul achievement rates of metals, for example, titanium, explicitly identified with protection from contaminations, have added to their driving position in the cranial implants market. North America is relied upon to overwhelm the worldwide market and record for a prominent share in the coming years."

The reports indicated that key players operating in the cranial implants market include Medtronic, Zimmer Biomet, Ortho Baltic, Stryker, Xilloc Medical B.V., Kelyniam Global Inc., KLS Martin Group, Medartis, DePuySynthes, and B. Braun Melsungen AG. ■

ORTHOWORLD Forecast *(continued)*

specialty metals service center and distributor based in Dayton, OH, which provides materials and value-added services for contract manufacturers, many of whom work as vendors for OEMs that produce medical implants, devices and instruments. ■

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osteoporosis. However, the market segment expected to undergo the fastest growth is extremity implants, which is anticipated to grow at a CAGR of 6.2 percent through the forecast period. This segment covers reconstructive implants for the small joints—ankle, digits, elbow, shoulder, and wrist—and is building on the established success of hip and knee implants. High growth in this area is powered by the increasing awareness of patients and physicians alike, of small joint implant options, and technological innovations contributing to more advanced implant designs." ■

Titanium, Zirconia Vie for Dental Implant Applications; Improvements from C-ECAP Technology Under Review *(continued from page 16)*

cable, composites and assemblies.

An online article from the January/March 2019 edition of the Journal of Materials Research and Technology (www.sciencedirect.com/science/article/pii/S2238785418302813), published by Elsevier/ScienceDirect, made note of the ECAP technology. "During the last 60 years commercially pure titanium was the main biomaterial used for dental application. (It) was adequate until now because the dental implants had diameters larger than 3.75 mm. The most recent dental implants and new dentistry surgery techniques use narrower implants (less than 3.0 mm) and commercially pure titanium does not have enough mechanical strength to support oral loading in all jaw sites… In the present work, a modified titanium Grade 4 material is proposed for narrow dental implant application. A new version of Grade 4, called "Ti G4 Hard," was hardened by the ECAP process and nanograin size was developed by severe plastic deformation."

The article concluded by saying that a dental implant's surface characteristics (morphology, roughness, macroporosity and microporosity) are critical for the success of dental implants, and that implants made with titanium Grade 4 Hard, submitted to a severe plastic deformation via the ECAP technology, are more resistant to compression and fatigue load than those made with conventional commercially pure titanium.

Separately, Maciej Krystian, a scientist with the Biomedical Systems Center for Health and Bioresources at the Austrian Institute of Technology (AIT) GmbH, presented information on ECAP during a presentation at the May 2019 TITANIUM EUROPE Conference and Exhibition, hosted and organized by the International Titanium Association, which was held in Vienna. Krystian reviewed the "Latest Achievements in Titanium Proceeded by Equal Channel Angular Pressing (ECAP)." Krystian said that Ti-6Al-4V ELI (extra low interstitials) is one of the most widely used titanium alloy for medical implants. ECAP, one of the severe plastic deformation (SPD) techniques, "achieves a strong microstructural refinement of metallic materials down to the sub-micrometer and even nanometer range, thereby increasing the strength without changing their bulk shape or sacrificing their ductility. Ti-6Al-4 V ELI after ECAP followed by a special thermomechanical treatment exhibits a tensile strength higher than 1300 MPa. This value means an increase of strength of at least 30 percent as compared to conventionally treated material.

As a consequence, he explained that load-bearing implants or implant sections made of ECAP-processed Ti-6Al-4 V ELI "can be designed smaller and thus enable maximum patients' mobility and quality of life. Moreover, the ultrafine-grained microstructure in ECAP materials is the origin of low-temperature/high-strain-rate superplasticity.

"The development and application of new materials and process technologies enables targeted improvement of material properties and the design and production of innovative implants," Krystian continued. "In this context, the AIS team collaborates closely with leading national and international research institutions and companies. Our research and development activities include both permanent and biodegradable metal-based implants." ■