CERAMIC TECH CHAT

Episode 60

Title – "Dental ceramics support oral health: Carolyn Primus"

INTRO

McDonald: "I'm Lisa McDonald, and this is Ceramic Tech Chat.

> Many patients and sometimes even dentists are not aware of the many ceramic materials that sneakily find application in tooth and gum maintenance and treatment. But for those in the know, there are certain ceramics that hold a dear place in their hearts."

Primus: "Well, you know, I mentioned the calcium cements. And they have to be my favorite because they're surprisingly useful in making a dental material that works."

McDonald: "That's Carolyn Primus, medical device consultant and adjunct associate professor at Augusta University in Georgia. She has spent more than 35 years working with dental materials, particularly for endodontic applications, and will be publishing a book through ACerS–Wiley this fall that provides an expansive overview of everything she knows about ceramics and dentistry.

> In today's episode, Carolyn will share her journey into the dental world, provide a glimpse of the history and variety of ceramic materials used in dentistry, and describe some of the ways she's personally contributed to this field."
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> (music)

SECTION 1

Primus: "So, you want to know how I got into ceramics. Well, that was my bachelor's degree from the University of Illinois at Urbana[-Champaign]. And that's also when I joined ACerS, and I've been a member ever since."

McDonald: "So, it is quite surprising that you were able to get a B.S. in ceramic engineering because a lot of our guests learn about this field of ceramic engineering later on in their careers. So, how is it that you came to know to major immediately in ceramic engineering going into college?"

Primus: "That was through my high school chemistry teacher who ended up having a brochure from U of I that talked about both phase diagrams and the space program. Well, that I thought was great, so I immediately applied for that as my major.

But I realized that a bachelor's degree was not enough. So, I earned my master's and Ph.D. degrees from the University of California, and I obtained these while I was working at Sandia National Labs in Livermore, California.

Next, I wanted a little broader experience, so I was selected for a postdoc position at the Naval Research Lab in Washington, D.C., and that was fun. But I decided I wanted to get into industrial applied research, so I took a position at Gillette to support their product lines and develop new things.

During that time, I did work on ceramic razor blades, but I also earned a certificate in business administration from the executive development program at Simmons College in Boston, which helped me later when I joined the Ceramco division of Dentsply, the world's biggest dental company, to develop new ceramic dental products.

But then I took a twist after my husband retired, and I decided to consult on medical devices. I was able to receive an SBIR, or small business innovative research grant, from NIH [National Institutes of Health] and ended up founding my own company, Avalon Biomed Corporation.

But that was through the lucky connection I had with Doctor James Drummond, who was at NIH at that time, and he's both a dentist and a ceramic engineer from the University of Illinois. So, he could really appreciate my ideas and how they'd contribute to dentistry, even though I wasn't a dentist."

McDonald: "That is really exciting how it kind of went full circle for you, that you started at the University of Illinois, then later when you started your own business, you got to work with someone from the University of Illinois."

Primus: "Yes."

McDonald: "So, when you first started working with ceramic materials, what type of ceramics were you working with?"

Primus: "Well, I was working on nuclear weapons safety. So, there was some exposure to both glass as a sealing material and solid ceramics. And then I got into molten salts as a high-temperature material. So, I was applying sort of the same concepts of ceramics to something that was molten and their interaction, their decomposition, high-temperature properties.

Should I tell you a funny story about that?"

McDonald: "Oh, I love funny stories, yes."

Primus: "So, as a freshman, I went to a special lecture in [the] engineering hall, and the topic was going to be biomaterials. That sounded great to me. And I went into the lecture hall, and there were very few women in engineering then, and I was the only one in a very large and

full lecture hall. So, this was 1971. I was 17, and I certainly was not as sophisticated as college women are today.

So, the lecture was about breast implants, and the large male audience was very eager to be at this lecture because they could see nude pictures of women before and after they got the breast implants. So, needless to say, I was uncomfortable.

So, this idea of the new field of bioengineering certainly interested me, but this lecture deterred me, and my first job I took in the safer, nonbiological field of nuclear weapons safety. But luckily, 15 years later, I was able to contribute to biomaterials through working with dental materials."

McDonald: "Well, I am glad that that one lecture didn't turn you off for the rest of your life, and that you did find your way back to biomaterials. It is such a big, growing field right now with so many cool things there.

So, with the dental ceramics, as some of our listeners may or may not know, humans have been using ceramic and glass for actually quite a long time to help do repairs and treatments and maintenance of their teeth. So, can you provide us a little bit of a history of using these types of materials in the dental world?"

Primus: "Sure. People have problems with decay, broken teeth, loss of teeth throughout human history. People tried to rectify their problems with making little bits of teeth or horns or bones from other animals into replacements because those are relatively hard, durable, tooth-colored, and they could be shaped in a primitive way to replace teeth. People were unaware that these partially mineralized tissues contained ceramic crystals, specifically hydroxyapatite, which is now quite important in the dental world, but not for replacing teeth but for bone grafting.

So, this process of using teeth and bones to make replacement teeth and dentures persisted until about the modern dental era, starting in the 18th century. But now dental treatment has really evolved from such rudimentary things to a period where there's hygiene and restorations of your coronal dental anatomy, which includes dentures. But in the 21st century, we're looking at minimally invasive dental treatments, better diagnostics, regeneration of pulp and periodontal tissue, and these are all the state-of-the-art practices.

Right now, there are a lot of crystalline ceramics and glasses that are used for a myriad of dental procedures that are performed today. Most people relate to ceramics because they've had some problem with their coronal anatomy: they chipped a tooth, they had a filling. That's called restorative dentistry.

But even over my short 35 years in dental materials, things have really changed. We used to have lots of porcelain enameled metal crowns and bridges, which are great, but they're really not so popular now. Now what most people will experience are that they are getting a filling, which involves a lot of very specialized silicate glasses that are embedded in a

polymer matrix. Or if they're getting a crown or bridge, they're going to get something made out of lithium disilicate glass-ceramic or a zirconia, usually stabilized with yttria.

But even beyond those restorative things, there's a lot of other glasses and ceramic crystals that are used in dentistry, including ancillary uses of ceramics. There are ceramic lasers, and there's all these ceramics that are used in electronics that no dental office would be able to run without them. Plus, there's all the things that go into making a dental drill and dental abrasives that are crucial. And as we mentioned before, the hygiene treatments both at home and in the dental office."

(music)

SECTION 2

McDonald: "So, we know that within the dental field, you're specialized in endodontics. Can you provide our listeners a clear definition of what endodontics is?"

Primus: "Endodontics is the treatment of the pulp system within the tooth. The pulp is a very complex tissue having connective tissue, blood vessels, nerves in it. It's crucial to the health of your tooth and keeping it in place. But bacteria like to migrate and eat away at the enamel and penetrate and eventually infect the pulp. Well, that's not good. So, we have to treat that, and that gets into endodontics.

When I got into the consulting mode, that's when I got into endodontics, which I loved because it wasn't just replacing, you know, and trying to mimic the enamel that was lost; you were really trying to heal the tooth and prevent it from any further illness that often leads to extraction."

McDonald: "I think that's actually a beautiful thing to point out, that it's about healing the tooth. So often sometimes we think just about replacing: throwing out the old, bringing in the new. And even with as much as we have improved with our materials science in recent years, it's still what nature has been able to create, being able to preserve that original tooth that we have, to help heal those original tooth that we have is typically much better for us in the long run than if we have to do, you know, like the surgery of extraction, putting new things in.

So, that is really beautiful to hear that, you know, you got into this field because you want to focus on helping heal what we have. Of course, there are situations, like you said, where we do have to reconstruct, replace, but being able to preserve what we have while it's possible, it's nice that there's so much research in that area as well."

Primus: "You're absolutely, a hundred percent right because implants are not as good as your own teeth for a myriad of reasons, but partly because when you stick them into the bone, you try to get them stable, but they don't have the same support system and a system of springs called the periodontal ligament to enable them to absorb the stress of chewing."

McDonald: “So, for our listeners, let’s maybe give them a little journey through, they have probably heard of root canals. It used to be considered one of the most painful dental procedures, but nowadays, thanks to all of our innovations, it really isn’t too much worse than getting a filling from what I’ve heard. So, can we kind of walk our listeners through how do you keep your teeth healthy, what materials do we use at that point, but then as it progresses, the types of materials you need to do if you do need to go through a full root canal treatment and then post-treatment.”

Primus: “Well, regular trips to the dentist are important, X-rays are important, examinations, your hygiene, professional hygiene are all important so that disease can be spotted and treated as soon as possible. Otherwise, root canal therapy can end up being, it’s an irreversible disease of the pulp and needs to be treated.

Now, root canal therapy is a lot better these days, partly because of the instruments that are used and the methods that are used and the anesthetics. So, that part doesn’t really have to do with ceramics, but the treatment is important because when you need a root canal, you take out the entire pulp, and then you have to put something in there so you don’t have the bacteria from your mouth get into your jawbone, the alveolar bone, because that’s a disaster.

Now, ceramics come into that because when you go to refill the pulp space, it turns out that the ordinary cements of our lives, calcium silicate and calcium aluminate cements, are very handy for filling up that space. Sometimes with the combination of a gutta-percha rubber point, but the real sealing of the tooth will occur with the calcium silicate and calcium aluminate cement.

Now, there were other materials that were quite good for this, like epoxies. But the serendipitous finding for the calcium cements is that they are biomineralizing. That means that when they’re in contact with your body tissues, the ions come out of the cement, the phosphate that’s present in all body fluids react, and a superficial layer of hydroxyapatite is formed on top of the cement. Well, that’s just magical because it reduces the foreign body response to this strange cement being embedded in in your mouth, and the body responds with all sorts of cytokines to cause healing over that, regrow the bone, even regrow the tissue I was telling you about, the periodontal ligament, so that the healing of the tooth, the end of the root is better with these ceramic cements than with an epoxy.”

McDonald: “Awesome. So, we have gotten to talk about quite a wide variety of materials that are used in endodontics and in dental care, and it’s exciting to know that you have actually contributed to this field by patenting and developing some materials and products of your own. So, can you share with us some of these inventions that you’ve had that are used in the endodontics field?”

Primus: “The products that I’ve developed for the endodontic field began with White ProRoot MTA, which is calcium silicate cement. And then when I started my own company, I wanted to improve on some of those so that there would be no discoloration of teeth and perhaps some improved handling properties for dentists especially. So, I invented, and I

commercialized, NeoMTA and NeoPUTTY and NeoSEALER Flo, but I had a lot of publications on calcium aluminate cements for dentistry, too, which came under the names of Capasio and Generex, and it, so it was an evolution."

McDonald: "And that is how I think a lot of the best inventions are, is they are an evolution as we learn new things, as they hit the market, and we can really get that data from in-operation use to improve and just always make it better.

So, we've talked a lot about how even within the past 35 years that you've been working in the dental field, how there's been so much evolution in the materials and the designs and technologies used in this field. What are you most excited for and what do you expect for the areas of research to innovate in in the future for this field?"

Primus: "Well, dental companies are constantly researching and striving for more durable materials and often more esthetic materials. But it really depends on the indication whether they're going to be above the gum line or below the gum line.

Biomineralization can be necessary in the way that I described for the cements or other kinds of bioactivity as described by Larry Hench by the interaction of ions that are released from dental materials, including fluoride. Fluoride is really so handy for keeping our teeth because it will harden the hydroxyapatite.

Of course, nanomaterials offer unique properties, and there are some nanomaterials that are used now, but they're kind of hidden in their uses.

Right now, the subtractive manufacturing techniques for ceramic crowns and bridges are very important, where you use partially crystallized lithium disilicate and zirconia and then you follow it up with another heat treatment. Additive manufacturing is used now for night guards and for dentures with polymers, but there's a lot of research that's being published for indirect restoratives, like I've described before, for crowns and bridges.

In the future, I think that we're going to see there's more acceptance of zirconia. So, more zirconia implants and abutments will be used; they may become as common as titanium.

And the synthetic bone grafting materials are also really important, to time them to resorption of real bone, and it expands how we can treat people for restorative dentistry and oral health."

(music)

BREAK

McDonald: "The American Ceramic Society's Bioceramics Division is dedicated to stimulating the growth and activity of the Society in the areas of the science, engineering, and manufacturing of bioceramics, biocomposites, and biomaterials. Learn more about this Division at www.ceramics.org/bioceramics."

SECTION 3

McDonald: “So, you have done such a great job being a pioneer yourself in this field of dental materials, but I know you’re also been doing quite a lot of work to help support and inspire the next generation of women coming into these fields by helping to fund some scholarships, specifically through your alma mater, the University of Illinois at Urbana-Champaign. So, can you tell us a little bit about how these scholarships came to be and what inspired you to fund them?”

Primus: “Donating time and money to support engineering science and those less fortunate than I am now have been a priority for my husband and I. He could see that I wanted women of limited means to be able to study engineering, so scholarships and gift annuities are opportunities to support students and to support the outstanding University of Illinois Grainger College of Engineering.

But another passion of mine in that I have been a volunteer for the American Dental Association, working on their standards committees on topics such as abrasives, cements, ceramic restoratives, and dentifrices, and I serve as a chair for the Endodontic Materials Committee, like we’ve been talking about. Now, these are committees which can be tedious, but they’re important to industry, they’re important to the FDA, and they’re very important to foreign trade because the requirements for dental materials all over the world are coordinated through the International Standards Organization, of which the ADA is an affiliate.”

McDonald: “I think that is so important to look at how it connects on so many different levels: on a personal level, on a society level, on like that international global trade level. There’s so many different levels to this that it’s helping to support by involving your time and money in these types of initiatives.

So sometime this fall, your upcoming book, it’s going to be publishing. And what is the name of the book?”

Primus: “It’s ‘Ceramics in Dentistry,’ but it has a subtitle of ‘Materials Manufacturing and Clinical Applications’ because I want to sort of weave a tapestry of everything that I’ve learned about ceramics and dentistry and the history of ceramics into a text that’s accessible to engineers and dental students and dentists to sort of enrich their experience of dental materials.

So, you get an exposure in the book to regulatory processes, to requirements, and also you get an appreciation for how ceramics are made, how complicated it is to make them either as a powder or as a solid device, and how it ties in with industry. So, perhaps people in industry can also get a better feeling of what’s needed in a clinical setting.

And anybody that reads it, I want to make it accessible so that it would be somewhat entertaining and you would leave knowing the difference between what a filling is and

what a ceramic cap is and appreciate some of the ceramic science that went into its creation."

McDonald: "Thank you so much for adding those additional details. And like you said, being able to have a behind-the-scenes of the regulatory framework and processes is going to be very fascinating. I can't wait to see more about that because getting medical materials and devices onto the market can be quite complex as I've known from some of our previous guests. So, having a more behind-the-scenes look at that should be very fascinating for listeners and the readers once your new book comes out."

Primus: "Well, thank you."

McDonald: "So, as you've been a member of ACerS and, you know, now you're working with ACerS-Wiley publishing to prepare your newest book, what have you found to be the most personally or professionally enriching part of your time interacting with The American Ceramic Society?"

Primus: "I've always found that the publications and the meetings provided me with an opportunity to broaden my knowledge of topics that were even outside my regular work or to give me new insights into a specific topic. And these days I find the webinars that are offered by ACerS very helpful. Now, exposure to new ideas is very important for anybody who goes into applied research. It stimulates your creativity, and I applaud the Society for having these sorts of activities."

McDonald: "And we're very glad that we're able to offer these types of activities because, like you said, one of the biggest hurdles is just letting people know that these materials, these career paths, they're out there, there's something they can interact with, they can learn about, and they can help support. So, we have an even bigger, brighter future for all of our fields where ceramic and glass materials are used."

Primus: "Yes."

(music)

CONCLUSION

McDonald: "The next time you go in for your dental checkup and cleaning, take a moment to appreciate how even in this realm, ceramics are working to help keep your teeth healthy and strong."

I'm Lisa McDonald, and this is Ceramic Tech Chat."

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“Visit our website at ceramics.org for this episode’s show notes and to learn more about Carolyn Primus, dental ceramics, and her new book. Ceramic Tech Chat is produced by Lisa McDonald and copyrighted by The American Ceramic Society.

Until next time, I’m Lisa McDonald, and thank you for joining us.”