The History of RDA & Modern Erosive Tooth Wear

The following is a transcription that has been taken verbatim from the presenter's audio. No Edits have been made.

Video Transcript

Overview:
I'm going to be talking today about the history of RDA and modern erosive tooth wear. So this is a subject that I started my research on when I joined the Procter and Gamble company, and it's a topic that's near and dear to my heart. So I'm going to talk about an evidence-based significance of toothpaste, abrasiveness or toothpaste, RDA, and we'll talk about what that means and what that means in the clinical context of tooth wear and how to interpret the science and an evidence-based way to protect your patients teeth for their for their entire life. We're also going to talk about the primary drivers of tooth where including tooth erosion and how stannous fluoride is an evidence-based intervention for tooth erosion. So here we go.

Introduction to RDA:
For people that are just joining us and are sort of new to the topic of dental erosion or sorry, dental abrasion, you'll hear RDA mentioned a lot. So what does RDA mean? RDA stands for radioactive dentin abrasion and it's a method that researchers use to measure the toothpaste abrasiveness in dentifrice products, and it's used globally around the world. It's required in some geographies by boards of health to be reported on dentifrices for sale in those countries and it's a standard that's been used for a very long time by dental manufacturers and the American Dental Association to help ensure products are safe for lifetime of use.

So radioactive dentin abrasion was a method that was created because tooth abrasion is actually pretty difficult to measure. Early on in the development of toothpaste, abrasive testing some folks tried to weigh teeth, but that's complicated because they're hydrated and they'll dry out during weighing, so made weighing teeth hard. There were some early techniques, which we'll talk about that tried to use the shadows that teeth would project onto grass paper to actually magnify the amount of abrasion and measure it with rulers. We use even modern methods today using surface topography measurements using lasers to measure toothpaste abrasion. But in this particular method you start with a tooth and a tooth is a calcium phosphate crystal, and we send those teeth to a radioactive lab, and they are irradiated, and it transforms some of the phosphorus in the tooth into a radioactive version of that phosphorus. So we start with that irradiated tooth sample, then we brush it with a slurry of toothpaste in a machine that's called a V8 brushing machine. You have 4 toothpastes on toothbrushes on one side and four on the other, and this machine will brush back and forth and it will apply those strokes to the tooth and then we'll collect the slurry at the end. Then you put it on essentially a fancy Geiger counter, so you put it on what's called a simulation piece of equipment. Then you measure the radioactive counts from the slurry, and those the radioactive counts come from pieces of the tooth that have been abraded off by the dentifrice. So that all put together lets you determine how much toothpaste abrasion was done by an experimental toothpaste, and then you can compare it to a control toothpaste.

Development of the RDA Method

So the development of the RDA method didn't really spring, it's not where researchers started. So like I said, in the early 1900s, Dr. Miller working to understand these cervical notches. So those are the notches that form at the gumline between the tooth and the gingiva. They were trying to understand why these cervical notches were forming. So Dr. Miller recognized that they were forming and illustrated them in medical texts at the time. Uh, then researchers tried to recreate those cervical notches, which were observed to occur with toothpastes that contained abrasives when a cross brushing action was used. So in much of the early 10s 20s and 30s, researchers tried to develop substitutes for dentin. Dentin is hard to come by you would have to either get it from extracted teeth or from cadavers. So researchers were looking to try to find a substitute for that material. In over 100 years, there's still no substitute for dentin and its response to toothpaste. abrasive. So we still use dentin today in my laboratory, we collect teeth from over 60 oral surgeons, and we use dental tissues to help our research. So in the 40s, so that was all about dentin and people noticed it being worn away from the toothbrushing action. So through the 40s and 50s there was an attempt to create a brushing machine, which would then brush these extracted teeth in a regular way. So the first brushing machines you start to see them up here in the literature in the 40s. And Dr. Manly invented one of these brushing machines that became known as the V8 brushing machine. Eventually it worked its way into what's called our modern V8 brushing machine. Researchers Kitchin and Robinson working at The Ohio State University, actually in collaboration with the Procter & Gamble Company in the 40s, we're trying to answer the question: How abrasive does your dentifrices need to be? Through clinical observations of stain removal and through clinical measurements of abrasives, it was determined that you could remove stain completely from the tooth surface if you limited its abrasiveness to 1 millimeter of cut depth in in the cervical notches produced in a V8 brushing machine in 100,000 strokes. And at the time, there were a number of dentifrices that would achieve 2-3 or 4 millimeters of cut depth. Around the same time, there were case studies being submitted to the American Dental Association on those 3-4 millimeter cut depths, really abrasive dentifrices, illustrating the damage and the cervical notches that could occur and an excessively abrasive toothpaste. So, fortunately, the standard of removing stain at this level cut depth excluded all of those toothpastes where case studies had observed an excessive amount of abrasion. So really, those researchers brought together the best in the dental stain control with known unsafe toothpastes and with known safe toothpastes to establish this limit. Manufacturers, largely at the time exceeded to this limit and redesigned their toothpaste to adhere to this, to this suggestion that abrasiveness be limited to 1 millimeter of cut depth than 100,000 strokes. But that's awkward to do that test, 100,000 strokes is about 7 days of continuous brushing. We can do about 20,000 strokes a day in my laboratory on a V8 machine and that's really brushing for 8 continuous hours. So you want to give some people some breaks and things like that during the day, it's a complicated experiment to run. So Grabenstetter in 1958, working at the Procter & Gamble company developed the radioactive tracer method that we used today called RDA.

So, Dr. Bouchal working at actually Colgate Palmolive in the 60s, worked to standardize that method, including the force that you'd apply to the toothpaste to the tooth through the toothbrush while you're brushing with toothpaste and worked to publish the RDA of a variety of toothpastes that were sold in the market at the time. And it was really the first time that we saw standardization of the industry towards a single a single method, and we see a number of toothpastes that were eliminated from the market from this collaboration led by Dr. Bouchal. Dr. Stookey and Dr. Muhler in the 1960s investigated a number of different parameters of abrasives on dental hard tissues like enamel and dentin. Dr. Muhler is famous. Joseph Muhler is famous for inventing fluoridated toothpastes, and Dr. Stookey worked with him at Indiana University, where a lot of his early research was not only on fluoridated toothpastes but was also on abrasives. The reason why abrasives and fluoride toothpaste research was connected at the time is because abrasives or fluoride is very sensitive to abrasives and abrasives can deactivate fluoride. So research in the 70s were sort of joined at the hip between toothpaste abrasives and fluoride. I met Dr. Stookey early in my career at the PG at working at P&G and he actually passed away a few years ago and he was he was really wonderful, wonderful person and a great researcher. Umm, so throughout the 60s. Dr. Stookey published a lot of information about the linearity of dentin abrasion. So if I brush it for 1000 strokes, the amount of dentin that's removed is the same as what's taken away in the next 1000 strokes, and the next 1000 strokes. And the same thing for enamel, dentin wears about 10 times as fast as enamel does, so it's a much more susceptible dental hard tissue to toothpaste abrasives. And that's why it's the standard that we use to ensure that toothpastes are safe for a lifetime of use. And then in the 1970s, Doctor Heffernen, who I also got to meet, published what we what we think of today is the ADA as the final really ISO method or at the time the ADA method to standardize RDA globally.

RDA Standardization

So the development of the RDA method didn't really spring, it's not where researchers started. So like I said, in the early 1900s, Dr. Miller working to understand these cervical notches. So those are the notches that form at the gumline between the tooth and the gingiva. They were trying to understand why these cervical notches were forming. So Dr. Miller recognized that they were forming and illustrated them in medical texts at the time. Uh, then researchers tried to recreate those cervical notches, which were observed to occur with toothpastes that contained abrasives when a cross brushing action was used. So in much of the early 10s 20s and 30s, researchers tried to develop substitutes for dentin. Dentin is hard to come by you would have to either get it from extracted teeth or from cadavers. So researchers were looking to try to find a substitute for that material. In over 100 years, there's still no substitute for dentin and its response to toothpaste. abrasive. So we still use dentin today in my laboratory, we collect teeth from over 60 oral surgeons, and we use dental tissues to help our research. So in the 40s, so that was all about dentin and people noticed it being worn away from the toothbrushing action. So through the 40s and 50s there was an attempt to create a brushing machine, which would then brush these extracted teeth in a regular way. So the first brushing machines you start to see them up here in the literature in the 40s. And Dr. Manly invented one of these brushing machines that became known as the V8 brushing machine. Eventually it worked its way into what's called our modern V8 brushing machine. Researchers Kitchin and Robinson working at The Ohio State University, actually in collaboration with the Procter & Gamble Company in the 40s, we're trying to answer the question: How abrasive does your dentifrices need to be? Through clinical observations of stain removal and through clinical measurements of abrasives, it was determined that you could remove stain completely from the tooth surface if you limited its abrasiveness to 1 millimeter of cut depth in in the cervical notches produced in a V8 brushing machine in 100,000 strokes. And at the time, there were a number of dentifrices that would achieve 2-3 or 4 millimeters of cut depth. Around the same time, there were case studies being submitted to the American Dental Association on those 3-4 millimeter cut depths, really abrasive dentifrices, illustrating the damage and the cervical notches that could occur and an excessively abrasive toothpaste. So, fortunately, the standard of removing stain at this level cut depth excluded all of those toothpastes where case studies had observed an excessive amount of abrasion. So really, those researchers brought together the best in the dental stain control with known unsafe toothpastes and with known safe toothpastes to establish this limit. Manufacturers, largely at the time exceeded to this limit and redesigned their toothpaste to adhere to this, to this suggestion that abrasiveness be limited to 1 millimeter of cut depth than 100,000 strokes. But that's awkward to do that test, 100,000 strokes is about 7 days of continuous brushing. We can do about 20,000 strokes a day in my laboratory on a V8 machine and that's really brushing for 8 continuous hours. So you want to give some people some breaks and things like that during the day, it's a complicated experiment to run. So Grabenstetter in 1958, working at the Procter & Gamble company developed the radioactive tracer method that we used today called RDA.

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RDA Standardization

And that, that global recognition is used and accepted by a number of boards of health. It's been administered by the International Standards Organization (ISO), and it's supported by the British Standards Organization, the World Dental Federation (FDI), the American Dental Association, and it's even referenced in some early in early monographs in the in the Anticaries monograph by the by the FDA.

It's really important at the same time, to know what the RDA method is not used for, it's not intended to predict abrasivity of toothpaste in the mouth with any fidelity. It's not intended to determine if one toothpaste is more abrasive in the mouth when it's underneath 250. Remember what we're trying to do is isolate things that were four times as abrasive as 250, something within our RDA of 1200 strokes or 1000 strokes. Once you get underneath 250, the fidelity of the method to correlate with clinical wear is dramatically reduced, and we'll talk about what that means in a little bit. Let's keep going. Let's keep going from there.

RDA Value and Key Considerations

So normal toothbrushing habits play a big role in how teeth actually wear, and those toothbrushing habits are absent from the RDA method. Umm, So really what the RDA method is designed to do is to accurately measure the laboratory abrasion of a toothpaste, not the clinical abrasion of a toothpaste. And it's designed to limit that laboratory abrasion to a level where clinical wear was not observed. Remember, if we go back to what Kitchin and Robinson did, they created a laboratory method for toothpaste abrasives, and clinical measures of stain removal and clinical observations of tooth damage. So this laboratory method was used to isolate things that were clinically damaging from the marketplace, sort of the corollary to that is are things that are underneath the limit are not damaging, are not clinically damaging. So in spite of that official position, that anything underneath the score of 250 is safe for a lifetime of use, there's still some misunderstanding about why the limit exists and what the actual number means underneath that limit.

Cleaning Potential and RDA

So today a majority of dentifrices contain hydrated silicas that have very high cleaning scores, but not always high RDA scores. So, since these high abrasive toothpastes were eliminated from the marketplace, manufacturers like Colgate and Haleon and Procter and Gamble have worked to create what we call efficient cleaning abrasives. So those abrasives that remove a lot of stain, but generally do very little damage to the tooth surface.

RDA Testing Vs. Real Life Conditions

So if we think about RDA testing versus real life conditions, there are a number of differences. So one, in RDA testing, there's no pellicle. In real life, there's a pellicle, that pellicle takes time to remove before the abrasive even reaches the tooth surface, and that pellicle reforms rapidly after it's injured, through chewing or brushing or whatever, through drinking erosive beverages. And in RDA testing, there's continuous brushing of a tooth surface. In real life, the tooth sees about an average of five seconds per surface of brushing. So, umm, it would be an enormous amount of continuous brushing, especially when you consider the contribution of the pellicle to protect the surface and to lubricate the surface against the abrasives. And RDA testing paste and brush are the only elements, and the tooth surface is immediately accessible to the brush. In real life, there are a number of habits, including like where people brush, how they brush. Do they use a back-and-forth motion and up and down motion and oscillation-rotation, power type motion. Do they brush a long time, a short time, do they brush with high force or low force and all those things impact tooth wear rates. RDA testing really only counts for abrasion, while in real life abrasion is a small factor in tooth wear. And we're going to show what that means later. And we brush dentin in RDA and really, during the lifetime of brushing, most people are brushing enamel. So let's talk about what all that means and how all that impacts how we understand RDA and some clinical measurements of tooth wear.

Misinterpretations of RDA Values

So there are a number of misinterpretations of RDA values. You see a number of these things on the Internet. You see that there's a low, medium, high and harmful limit of abrasivity. This is just not true, so the graphs that I showed you earlier, the limit of 250 was set in order to eliminate RDA's of 1000, 1200, 750. Everything underneath 250 removed stain, and it was not clinically observed to damage the teeth. So these things really are not based in the research science that was used to establish RDA. And you see a lot of these things in Wikipedia, and you see them on the Internet.

Clinical Evaluation of RDA and Tooth Erosion

So let's talk a little bit. So all that all that being true, let's remember that anything underneath an RDA of 250 was designed to be safe for a lifetime of use, and if it's underneath an RDA 250 it was not observed to be clinically degenerate, a clinically meaningful amount of erosion or abrasion. If that is true, then clinical measurements attempting to measure clinical abrasion differences for our low RDA toothpaste beneath 250, they should not be able to see clinically meaningful differences. But that's the hypothesis they actually shouldn't be able to tell these two states apart. Dr. Volpe, working for the Colgate company, I think actually was also might have been working at the American Dental Association at the time too. Umm you used a long term randomized controlled clinical trial to compare two dentifrices of different RDA values. They actually did this in a controlled population of people, so it's supervised brushing. Twice daily brushing and RDA of 50 versus an RDA of 90. They took a baseline clinical examination of cervical abrasion and cervical erosion. So they measured these cervical notches and depths of them, and they measured again at three-month intervals, and they measured for 54 months. So we're talking four years and six months, and they measured cervical examinations every three months. So when you plot the amount of cervical abrasion, so this is just the average number of abrasion or erosion teeth per subject, right. So there's no difference in the amount of teeth that had cervical notches over the 4 1/2 years. Umm, there's no statistical difference regarding this cervical tooth wear for these two toothpastes underneath an RDA of 250. But I think this is a really interesting study and it's one of the very first studies done in the 70s, but then tried to look at differences in tooth wear for RDA toothpastes beneath 250. This still doesn't answer the question though, are those numbers fundamentally safe, and we'll continue on that journey, and we'll get an answer to that. So Saxton, 1980 used again a randomized controlled double-blind trial, and this case with parallel groups to in two separate studies comparing two different dentifrices of differing RDA values. And really looking at the impact of daily brushing, again twice daily brushing on the development of cervical lesions. So in the first study, fifty people were randomized into two groups, RDA 55, RDA 100 and the second study that had an RDA of 19 and RDA of 119. So the even bigger difference between them. They identified 2 cervical lesions. They tracked the depth of those cervical lesions; they washed out and then they crossed over. My apologizes, looks a parallel phase as a crossover study and they repeated that work and this is what they found. What they found is that there's no difference in dentin loss. No statistical differences in dentin loss are found. Nearly identical differences in dentin loss for RDA and identical differences for dentin loss at the 19 versus the 119. So no significant difference between toothpaste underneath and RDA of 250 and that's what you would expect had the limit been set with regard to safety and efficacy, both the clinical safety and the efficacy for stain removal. Again, though, it doesn't really answer uh how much cervical wear there would be if we tried to extrapolate that to a lifetime of use and we'll still get there.

Umm, so some in-situ model studies show differences between higher and lower abrasive products over a period of a few days, a few weeks, a few months, a few years. We still need to keep going and trying to understand aspects of erosion. We've not really touched on that yet, just sort of wear in general with controlled brushing. Umm, and we want to just consider the long-term implications of tooth wear behind high and low abrasives. Up to now no differences. So that's exactly what we would expect. So now Pickles, I actually got to meet Dr. Pickles at several conferences early in my career. At the time that he worked for, GSK used an in-situ model randomized controlled double-blind trial. In this case this was parallel, and this is an in-situ model where they actually placed dentin chips and enamel chips into appliances that people were able to brush and they followed these for 24 weeks, so about six months. And there were clinical examinations of dentin wear along the trial at 4, 8 and 12 weeks. In this case, they were comparing an RDA of 90 with twice daily brushing to an RDA of 204. I think this is one of the first studies that really tries to get at what are the clinical measurements manifestations of wear and then trying to extrapolate that to a lifetime of wear. So first, no differences in clinical wear between 90 and 204 at 25 weeks. Numerically, the 90 was higher, but these are not statistically different, so we'll consider them the same and then the authors go on to try to estimate that where after 80 years of brushing and it's less than 1000 microns or less than a millimeter, or roughly the thickness of a penny. So in 80 years of brushing the amount of dentin that is worn away would cause a cervical notch approximately 1 millimeter deep. I would say that is a clinically acceptable amount of wear, if the patient is able to use those dentifrices effectively to keep their teeth free from stain, free from harmful plaque and depositing fluoride at the tooth surface. So and certainly 1 millimeter of dentin in 80 years would not be considered a clinically meaningful amount of tooth wear.

In Vitro Testing of RDA

So I think what we've done to now is that in vitro abrasivity testing is not predictive of *in vivo* tooth wear when you're examining toothpaste with an RDA less than 250, an RDA that is safe for a lifetime of use. It really is useful as a tool for developing new products. I use RDA every single day to make sure that toothpastes are safe. And I use RDA every day to help me understand how effective they are at removing tooth stains. That's why RDA was invented, really, was to ensure that those toothpastes were effective at removing stain while not causing excessive damage to the tooth surface. So we use it to develop new formulations, to make sure that those formulations are the same every single day and they're safe through the lifetime. And really, it's to obtain a rough estimate of their potential for clinical abrasivity. In very gross terms; underneath 250 safe, if it's 500 where we may be getting to not safe, if it's 1000, it's definitely not safe for a lifetime use. It's not appropriate to derive RDA values alone to determine clinical safety, and that's especially true because dental wear is multi factor. I think we've established that abrasives do not have enough potential when they're formulated underneath 250 to cause clinical, clinically meaningful wear amounts. But in combination with other facets of people's lives, those abrasives and those choices that people make may create an unsafe situation. And what I'm alluding to there is the combination of acids and dietary acids is especially damaging to the tooth surface and then the combination of those acids with physical trauma to the tooth surface like abrasion like mastication, like biting your nails. Those types of physical traumas, in combination with acids, can be potent tools for damaging the tooth surface.

RDA Abrasivity Summary
So just to return, you'll see things like this on the Internet, it's just not true. So I think if a toothpaste is less than 250, you can feel confident about recommending its use for people for a lifetime of use. If folks have really exposed dentin, and if folks have really acidic diet, we need to have a conversation and that's what we'll talk about next.

RDA and Enamel
I'm so let's go back to the Pickles example for a moment and let's pivot a little bit to enamel now. So I think we've talked about dentin and RDA. We've not talked much about enamel, even though that's the primary surface that people are going to brush for their lifetime. So if we said that dentin, there was no difference. But if we then go to enamel again, there was no difference in the amount of enamel wear, but the enamel wear was significantly less than the dentin wear and about 1 Micron in 24 weeks. So if we estimate the amount of wear that dentifrices can cause to enamel in 80 years, it's 30 microns, which is like the width of a human hair. OK, so I know, I know people are shaking their heads, you know, they're saying "Sam but I've seen clinical wear, I've seen tooth wear and patients and it just has to be the abrasive." All I'm going to say is the there. I'm sure there's tooth wear happening and what is really the damaging thing for tooth wear is acid.

RDA Video
So let's pause here. We're going to watch a video to just cement this information. If Jed, if you would like to put that up and then we'll talk about erosive tooth wear.

(***Video voiceover***) *You may have heard that some in market toothpastes with higher RDA values are too abrasive and can damage enamel. This isn't true, and it's time to set the record straight. The RDA scale was originally developed as a laboratory method, using dentin to determine the point at which toothpastes could safely provide a cleaning benefit. The scale was never meant to simulate real life brushing conditions or intended to rank the safety of products, let alone predict the abrasiveness against enamel, which is ten times more resistant to abrasion than dentin. In fact, the position of both the American Dental Association and the International Organization for Standardization is that all toothpastes with an RDA value of 250 or below are safe for a lifetime of use, regardless of how high or low the RDA value falls within this range. It's like an elevator with a capacity limit of 15 people, it doesn't matter if the elevator is holding 12 people or 3, as long as it's not over the capacity of 15, it's safe for the elevator to operate. The same principle applies to the RDA safety limit of 250. Clinical evidence supports that lifetime use of a toothpaste with an RDA of 250 or less with proper brushing technique produces limited wear to dentin and virtually no wear to enamel. Of course, it's important that toothpastes actually clean teeth. To that end, the higher the RDA value of the toothpaste, the more effective it will be at cleaning and general. In closing, confidently recommend any toothpaste with an RDA value of 250 or below for a lifetime of safe use. And remember, generally the lower the RDA value, the less effective it will be at cleaning teeth.*

The Primary Driver of Tooth Erosion
Great. Thank you very much. So I hope that I hope folks feel more informed about RDA now, what it means. And the clinical manifestations of RDA and how we can measure or can't measure differences in clinical wear or for RDA less

than 250. Which really means that the original scale as it was developed was effective. Now when we paused before the video, I said, I know that some of you are shaking your head saying, I know that people are presenting with tooth wear. In fact, those tooth wear, it might even look like cervical notches. And I'm just absolutely convinced that it's the toothpaste abrasive. Let's talk about other ways and other choices that patients can make that amplify the damage that they're doing to their enamel or to their dental hard tissues.

So acid interaction, we already know acids bed for the tooth and the caries perspective. Let's talk a little bit more about dietary acids. So acid interaction with tooth surfaces, it is the absolute primary driver of tooth wear, not RDA value of dentifrices. I just, I cannot say this enough. It's the acid interaction with the enamel that is the primary driver of tooth wear. Enamel is an incredibly hard surface, but it is a mineral crystal and when that mineral crystal is exposed to acid, it's just dissolves, and once it has dissolved, once that crystal dissolves, any type of physical wear will remove it from the from the crystal underneath it. And I really do mean any type of physical wear. Once it's acid damaged; chewing the lips, moving across your teeth, the tongue moving across your teeth, the cheeks moving across your teeth is enough physical force to remove acid softened enamel from the tooth.

There are some sources of acid in our mouth and some people experience every single day. Acid from acid reflux, especially at night. Vomiting, that acid is an especially potent acid, it's extremely low pH and they can do quite a bit of enamel softening. And then there are extrinsic acids, especially those in acidic food, drinks and carbonated beverages. Fruit acids, especially those like citric acid, can be even extra bad for the tooth because they not only are sources of low pH that dissolve the enamel, but they also bind calcium. So as a tooth dissolves, it will release calcium and phosphate into the pellicle, and the fluid immediately to the tooth surface, and that dissolved enamel can buffer acids, and that calcium can replenish the enamel once the pH comes back up. But in the presence of citric acid, the citric acid will bind that calcium for example, and wash it away, making it even harder to remineralize the tooth surface. Food acids are also buffers, so you can have a lot of acid at a particular pH. So that means it's very difficult for your natural protective sources of neutral pH, like your saliva to buffer away those acids. So intrinsic and extrinsic acids, when they touch the tooth surface, they will soften them. So in these scanning electron microscope images, we have a slice of enamel here, there was a protected surface and then there was an area that was exposed to the acids, and it was dissolved away with exposed to dietary acids. That tooth was dissolved away, and as we zoom in at the interface of where the acid is and where the tooth is, you can see these little wisps of enamel, these little enamel crystal sort of filaments coming from the enamel surface. This is what happens on a sort of a molecular or crystal level, as the enamel is dissolved away by these by these sources of acid. And I think this picture drives home what I started this part of the section with, that any sort of physical trauma, any sort of physical contact with these sort of enamel wisps that have been acid softened very easily removes them from the tooth surface.

Drivers of Extrinsic Risk Factors

The number of factors can play into the damaging potential of tooth erosion. One is the buffer capacity of the acid, so you can have a low pH and then you can have a lot of citric acid. So a lot of citric acid at a low pH is doubly damaging because it's very hard to neutralize that acid because you might have a lot of what I just call chemistry, a lot of chemistry. And there are other protective factors that also come to play in low pH, things that we normally think of yogurt as low pH. But yogurt has calcium in it so that calcium balances the low pH to help protect the enamel surface. So and then some manufacturers that make low pH beverages actually put things like phosphate in them to protect the tooth surface. And then there's the acid type. Citric acid like I talked before, has a higher erosive effect because it can bind to the calcium and carry it away. So all these things add up to either make a damaging or not damaging or more damaging dietary acid, and we have to sort of think about them all at the same time.

Tooth Wear Erosion Management
So really, if you see a patient that presents with tooth wear, what you really need to do have a conversation with that patient about what they're behaviors are and introduce this concept, that diet and the diet choices they make can damage their teeth. And then you want to make behavioral interventions. So if they are consuming acid, get them to reduce acid. Get them to perhaps reduce aggressive brushing, reduce frequent brushing or to brush after the erosive events so that way you give the chance, they give the tooth a chance to mineralize. And you can also intervene with the choice of which toothpaste to use.

Stannous containing toothpastes are clinically proven to reduce erosive damage because they put a shield on the tooth surface, an acid durable shield on the tooth surface that prevents attack by acids. So really, if someone's presenting with tooth wear today presenting with tooth wear today, it's acid mediated. We have soft cooked foods today, so if someone presents with tooth wear it is most likely because it's acid mediated, they have a lot of acid in their diet. This isn't necessarily true for, you know, ancestral humans 10,000 years ago, when our diets were fibrous, less cooked, more dependent on grinding uncooked fiber stalks, where you can see a lot of physical abrasion. You just don't really see that today. What you see today is this wear, where you see this dissolution of cusps on especially premolar surfaces. You can see the loss of enamel where the fluid wash where acidic beverages wash over enamel. Umm, so that's really the much more common situation today. So finding out more about your patient is the important thing.

So I don't want to, I always try to resist putting too many graphs in a presentation, but this one is one that I used in my research that I think drives the point home. So we have a cycling experiment in my lab where we'll start with a human tooth, and then we'll treat it with a toothpaste and we'll put it in saliva, and then we expose it to citric acid and then goes back into saliva. Then we'll treat it with a toothpaste, into saliva, then into acid, then it to saliva. So those acid exposure times are either 10 minutes in the normal experiment or five minutes per cycle, or two minutes per cycle. And then we'll keep cycling that, four cycles a day for 10 days and we'll measure how much tooth wear there was. So if I have absolutely no acid in that cycling, I can barely measure the enamel wear. So this is just the enamel wear from the brushing.

As soon as I introduce 2 minutes of acid exposure, so we use PH-2 citric acid, so kind of like lemon juice, you might think of it like that or grapefruit juice. So we use lemon or grapefruit juice for two minutes four times a day, 10 days. I increased the amount of wear from almost unmeasurable to a factor of 10 or 20 times higher, and if I go from 2 minutes a day to 5 minutes a day, it goes another 2X higher and if I go up to 10 minutes a day it goes up almost 2X again, 1.5X. I can't say this enough that this increase from almost unmeasurable tooth wear for toothpaste abrasives, when I introduce just a little bit of acid, 2 minutes four times a day, I increase the amount of tooth wear by a factor of 10 or a factor of 20.

It really is the acid that's the imaging to the tooth surface. Now if we compare the blue line to the orange Line, the blue line is the brushing with sodium fluoride and the orange line is the brushing with stannous fluoride. Stannous fluoride in this particular experiment, reduced the amount of acid damage by about 20%, and when we measure clinically erosive tooth wear in an in-situ model, using a toothpaste brushing and citric acid challenges, we measure clinical reductions about 45%. And that's because stannous can interact with the pellicle to amplify the amount of protection that there is. We don't really have as durable pellicle in this experiment. But every time we measure stannous in these experiments in my laboratory and when I partner with my clinical scientist, we measure a dramatic reduction of erosive tooth wear for stannous fluoride in comparison to sodium fluoride.

Stannous Fluoride and Tooth Erosion
That's one of my favorite slides. I love that. Plus, I really think it just shows people how much acid potentiates the tooth wear potential of anything that happens in your mouth. So how does stannous fluoride work. Stannous fluoride

forms a barrier on the tooth surface so that the stannous in stannous fluoride, it's a type of anti-cavity tooth agent. The stannous, once it delivers fluoride to your mouth, it lets go of the fluoride. So fluoride can remineralize and then the stannous binds to the phosphate on your tooth surface, and it forms a layer, a stannous phosphate layer that is durable and it helps to repel acid attack. We've used stannous in a number of different forms and a number of different toothpastes at P&G for 30 years to help provide an acid erosion benefit (almost 30 years). And a number of other manufacturers also provide a stannous fluoride toothpaste that provides erosion protection.
So if we go then and consider, I'm going to show you some more laboratory results. I just want to compare stannous fluoride now with several different sources of sodium fluoride that you might be familiar with. So we start, like I said, we work with human teeth in my lab, so we take a core sample of enamel from a tooth. We put it into this plastic rod, then we cover it with nail polish, but we leave a little area exposed right here. That area is exposed to acid and toothpaste and these coated surfaces serve as a reference that allow us to have an undamaged surface to measure from. Then we do erosion cycling. So we treat that enamel for two minutes, we expose it to saliva for an hour, it goes into a 10-minute acid challenge, back in the saliva. So we did that four times a day in this experiment for five days. We then slice or we use a 3D surface mapping technique to look at the amount of area or the volume of enamel that was lost, or the amount of depth that was reduced from the control areas. So this is the treated area here. These are the control areas, and we can measure the amount of mineral loss right there.

So when we do that, this is the enamel loss over five days, with the stannous fluoride toothpaste underneath 10 microns. For sodium fluoride toothpaste, it's over 20, so it's more than two times higher. For a 5000 PPM sodium fluoride product, it's more than two times higher. For acidulated phosphate fluoride plus a sodium fluoride toothpaste, it is more than two times higher. The reason this is true is because once you're at pH 2, fluoride is no longer protective. Fluoride is protective against weak acids that are involved in caries, and those acids are like lactic acid. Those tend to have a pH of about 4-4.5 and fluoride is incredibly protective there, and it provides the remineralization potential to help restore damage from caries acids. But once you fall beneath pH 4 fluoride does not provide protection anymore, and you have to shield the enamel surface using something like stannous. So then clinicians partnered with researchers in the UK to do a randomized crossover in situ trial, double-blind trial. Where we looked stannous fluoride, sodium fluoride and water that preventing dietary erosion in twice daily treatment over 15 days. So then we measured the amount of surface loss at 5 days, 10 days and 15 days of these enamel chips that were placed into an appliance that were put in people's mouth.

So when we look at the enamel loss in microns at day five, there was stannous fluoride, sodium fluoride and water and at day 10 there's stannous fluoride, sodium fluoride and water. And at day 15 stannous fluoride, sodium fluoride and water. Water lost the most then sodium fluoride, then stannous fluoride. I just, and you might say, well, you just said sodium fluoride wasn't protective, but it's better than water. That is true. It is better than water. Fluoride does provide an ability to remineralize some of the damage between acid challenges that occur during the day and. And it can slow the acid damage as the pH is falling in the pellicle, which doesn't happen immediately when you expose to acid. The laboratory studies are difficult, we try to recreate a pellicle, but it's difficult. The clinical pellicles are more durable, and fluoride will have a small effect until the pellicle pH drops quite substantially, and it can remineralize. So that's the fluoride affect that you're seeing here. And then on top of that, you're seeing the shielding effect from stannous. So in this case, less than there was three times, more than three times the amount pf wear with water and more than two times the amount of wear with sodium fluoride in comparison to stannous fluoride. So when it comes to taking care of patients that are presenting with tooth wear, understanding their habits, understanding their dietary choices and then shifting them towards a more protective stannous fluoride toothpaste is helpful.

Stannous Fluoride vs. Arginine and Novamin
And then we can think about some of the other caries agents that folks, that are available to folks in the marketplace. So stannous fluoride, in comparison to arginine, stannous fluoride has a significantly higher protective effect versus arginine against dietary acids. Stannous fluoride versus novamin, or other bio glasses. Stannous fluoride again has a significantly higher protective effect versus other bio glasses or novamin in toothpaste.

Summary
The three things to take away here:

1. Dentifrices with an RDA value of less than 250 are safe for a lifetime of use.
2. The primary driver of tooth erosion and tooth wear is acid mediated and acid damage on tooth enamel.
3. Stannous fluoride dentifrices are clinically demonstrated to protect tooth surfaces, and they do that by forming a barrier that protects the tooth surface against acid.

So those are the real key take-aways here. I have been really delighted to share this with you. Umm so just in closing, there is a lot of wonderful research available to you. If you're looking for more research, more clinically, more clinical studies, you can always go to dentalcare.com. There are videos, images, there are publications. There are lots of other tools for at home oral care information, so feel free to take advantage of that. And then anyone that wants to reach out, I'm happy to provide some more information on the methods and any additional resources, but I'm going to pop back to the to the summary conclusion and wrap this up. Again, thank you to everyone for joining me tonight. I have a lot of passion for this topic. I've been doing research in this area for about 20 years now. I really care. I come to work every day really hoping to make products better so that they can live better lives. I believe passionately in the work that researchers like me and like other people do to create safe products that help people live better. And I really respect the work that dentists and dental hygienists do every day helping people lead healthier lives. So thank you so much.