HOPE & AWARENESS · ISSUE 01 · 6 JUNE 2026

Advances in Dentistry

Good news from dental science, in plain language — what is coming for your smile, and how soon you can really expect it.

9	3	100+
ADVANCES EXPLAINED	HOW-SOON STAGES	SOURCES REVIEWED

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On the Horizon

From peptide enamel repair to a 2030 tooth-regrowth drug: sorting real progress from the hype

SECTION 01

This Week's Big Hope

A self-rebuilding enamel gel and a tooth-regrowth antibody both show dentistry shifting from repair to regeneration — early, but real and peer-reviewed.

For as long as dentistry has existed, the job has mostly been to patch what is broken. A cavity gets cleaned out and filled. Worn enamel gets crowned. The reason is plain biology: enamel, the hard white shell on your teeth, is the toughest material your body makes, but it has no living cells. Once acid, sugar, or grinding wears it away, the body cannot grow it back. This week's hope is a result that pokes a hole in that old rule.

In November 2025, a team at the University of Nottingham published a peer-reviewed study in *Nature Communications* describing a fluoride-free gel that coaxes damaged enamel to rebuild itself. The gel is made from engineered proteins that copy the natural scaffolding our bodies use to build enamel before we are born. Painted onto a tooth, it soaks into the surface and forms a framework. That framework then pulls calcium and phosphate, the raw ingredients of enamel, out of saliva and organizes them into fresh, layered crystals that grow in line with the enamel already there and lock onto it. Under an electron microscope, a pitted, acid-eroded surface turned into orderly crystal growth that looked and behaved like the real thing, and the new mineral held up to simulated brushing, chewing, and acid.[1]

Why does this matter so much? Because tooth decay is close to universal, and almost every fix until now has meant removing healthy tooth to anchor a repair. A material that rebuilds enamel goes after the cause rather than the symptom. The shift it points to is from "repair the damage" to "heal the tooth."

The number that keeps this honest

The regrown enamel-like layer measured about 10 micrometers thick. Full natural enamel on a biting surface runs to roughly 2,000 micrometers, which is 2 millimeters. So this is a genuine first layer of healed enamel, not a regrown tooth. Be excited, but keep the scale in mind.

EXHIBIT 1

A real first layer, not a rebuilt tooth

Regrown enamel-like mineral vs. the thickness of natural enamel on a chewing surface

DENTAL NATION RESEARCH SOURCE: FUTURISM REPORTING ON THE NATURE COMMUNICATIONS STUDY (2025)

4

There is one more caveat that matters. The work was done on extracted human teeth in a lab dish over a two-week treatment, not inside a living mouth. The authors say plainly that confirming true enamel regeneration will need testing in real people. A Nottingham spin-off called Mintech-Bio is now working to turn the gel into a product, with the lead investigator hoping for a first product within about a year and clinical testing aimed at early 2026.[2]

The runner-up: a drug meant to regrow whole teeth

The enamel gel is not the only sign that dentistry is leaning toward biology over hardware. In Japan, a drug called TRG-035 is the world's first antibody designed to regrow entire teeth. The idea is clever. Many people carry dormant tooth buds that never develop because a protein called USAG-1 keeps them switched off. TRG-035

blocks that protein, and in mice and ferrets a single dose grew complete, working teeth that fit in with the existing ones.

That animal work has now moved into people, carefully. A first-in-human Phase I trial began in September 2024 at Kyoto University Hospital with 30 healthy adult men aged 30 to 64, each missing at least one molar, in an eleven-month study focused on safety and dosing. The program got a real institutional vote of confidence on September 29, 2025, when Japan's health ministry granted it orphan-drug status for severe congenital hypodontia, defined as being born without six or more permanent teeth.

TRG-035 anti-USAG-1 antibody for tooth regeneration

TOREGEM BIOPHARMA (KYOTO UNIVERSITY SPIN-OFF) · PHASE I, KYOTO UNIVERSITY HOSPITAL · 2024–2025

By neutralizing USAG-1, the antibody reactivates dormant tooth buds. It cleared the lab in mice and ferrets and is now in a human safety trial, with Japanese orphan-drug designation as of September 29, 2025.
[5]

[6]

Here is the honest read on timing. No human has yet had a tooth regrown by TRG-035, and no human mouth has yet been treated with the enamel gel. The drug is in a safety phase, and its team targets availability around 2030, success permitting, first for a rare condition. So the takeaway is not that this is arriving at the pharmacy soon. The calmer and more remarkable reality is that two separate teams, on two continents, now have peer-reviewed and trial-stage science pointing the same direction: toward growing teeth back rather than drilling them out.[3]

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SECTION 02

Pain-Free Dentistry

Pain-free dentistry: what's ready now, what's oversold, and what's still years away

For a century, dentistry's image has been the drill and the needle. The fear that comes with them is not in patients' heads. A 2021 meta-analysis pooling 72,577 adults across 31 studies found that 15.3% live with dental fear or anxiety, and roughly one in three people put off or skip care because of it. That makes "pain-free" more than a marketing line. It is a public-health lever.

15.3%	12.4%	3.3%
ADULTS WITH DENTAL FEAR OR ANXIETY	HIGH FEAR	SEVERE FEAR

7

The encouraging part for an "advances" report is that the field is chipping away at pain and fear from several directions at once. The catch is that those directions sit at very different stages of maturity. A few are quietly ready in clinics today. Others are improving but oversold. And the dramatic stuff, the future where deep cavities heal without a drill, is still years off.

The quiet wins: stopping early decay with no drill, no needle

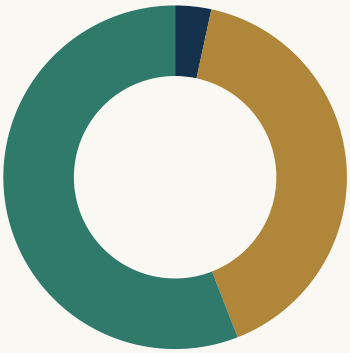
The most genuinely pain-free advances are the least hyped. They catch decay early and stop it cold, before there is anything to drill. Silver diamine fluoride is the clearest example: a liquid brushed onto a tooth, no anesthesia, no instruments. Pooled across eight studies, 38% SDF arrested about 81% of caries in baby teeth. Its one real drawback is cosmetic. SDF stains the arrested decay black, which is why it lives mostly in pediatric, geriatric, and access-limited settings.[1]

Resin infiltration (sold as Icon) does something similar for early lesions between teeth. A 2025 trial tracked initial proximal lesions for two years: none of the infiltrated lesions progressed, against 5% progression in untreated controls. Again, no drilling and no numbing.

EXHIBIT 2

Early proximal lesions: progression at 2 years

Share of early between-teeth lesions that got worse over two years



Resin infiltration (Icon)	0%
Remineralization	3.6%
Untreated control	5%

DENTAL NATION RESEARCH

SOURCE: J. FUNCTIONAL BIOMATERIALS (MDPI), 2025

8

Atraumatic restorative treatment (ART) belongs in the same family: decay removed by hand instruments, then sealed with glass ionomer, usually with no drill and often no needle. It holds up reasonably well, around 71% survival at one year and 67% at two, with single-surface fillings in baby teeth topping 97% at a year. Durability drops sharply for larger, multi-surface cavities and leans heavily on the operator's skill.[2]

One caution ties all of these together. SDF, resin infiltration, and peptide-based enamel repair only work on early, non-cavitated decay. Once there is a real cavity or a fracture, the drill is still the standard of care. Today's pain-free dentistry is, in large part, catch-it-early dentistry.

The maturing tools: better, but oversold

When drilling is unavoidable, lasers (Er:YAG and Er,Cr:YSGG) are the most-promoted alternative. A 2025 meta-analysis of 20 trials and more than 2,263 teeth found patients needed anesthesia far less often (relative risk 0.29) and reported less pain (RR 0.35), with no loss of restoration survival or pulp vitality. The asterisks are large.

The evidence was rated very low quality by its own authors, and lasers added about 2.2 minutes per tooth. An earlier Cochrane review found the evidence too thin to back lasers at all, so this remains contested ground.[3,4]

> **A useful rule of thumb**
>
> The technologies marketed hardest to patients (needle-free injectors, lasers) tend to have the weakest evidence. The quiet, cheap, genuinely no-drill wins (SDF, resin infiltration, ART) have the strongest.

Needle-free injectors and computer-controlled delivery systems make a similar pitch. The headline figures are eye-catching, like the roughly 70% pain reduction reported for The Wand in one periodontal-surgery trial (Wong-Baker 2.0 vs 6.7). But that came from a small single-site study, and rigorous head-to-head trials often find no meaningful difference against a careful conventional injection. A 2025 randomized cross-over trial covering 56 children's injections found no significant pain difference for a needle-free system. The real value is reducing needle phobia and improving cooperation, especially in kids. Treat it as a fear intervention, not a painkiller.[5,6]

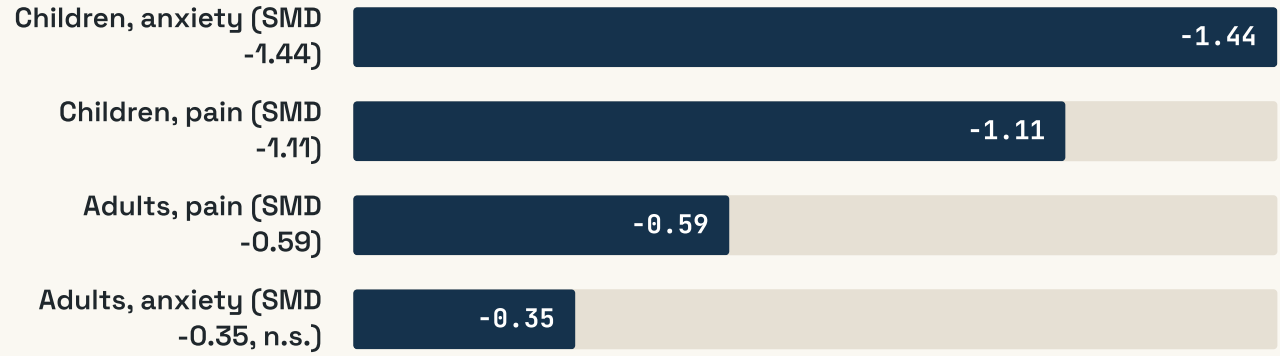
For fear, not pain: virtual reality

The strongest emerging tool for anxiety rather than physical pain is virtual-reality distraction. A 2024 meta-analysis of 27 studies found large effects in children, both for anxiety and pain, and a moderate pain benefit in adults. The nuance worth keeping is in the adults: VR showed no significant anxiety benefit for them at all. It works on kids far better than on grown-ups, and even the children's findings carry low-to-moderate certainty.

EXHIBIT 3

Virtual reality during dental care, by age

Standardized mean difference (more negative = bigger reduction)



DENTAL NATION RESEARCH

SOURCE: VR META-ANALYSIS (27 STUDIES), 2024

9

A recent randomized trial puts a finer point on the children's story. In 90 kids undergoing pulpotomy, VR distraction improved how well they adapted to treatment compared with cartoon distraction or none at all.

Reduction of dental anxiety in children using virtual reality: a randomised controlled trial

EUROPEAN JOURNAL OF PAEDIATRIC DENTISTRY · 2025

In 90 children undergoing pulpotomy, VR distraction improved how well kids adapted to treatment compared with cartoon distraction or none.

10

The frontier: years away, but real

The storyline that could one day make the drill obsolete for actual cavities is biological repair. The paper below is the honest frontier: real science, early stage, and limited to early lesions for now.

Next-generation strategies for enamel repair and regeneration: advances in biomaterials and translational challenges

PMC REVIEW · 2025

Self-assembling peptide P11-4 and biomimetic hydroxyapatite can coax the tooth to rebuild thin, early enamel lesions, but only for early, non-cavitated decay. Advanced decay still needs mechanical repair.

[11]

The honest throughline for the whole section: prevention and arrest for early decay is genuinely pain-free and ready now. Comfort tech for injections and drilling is a little better but easy to overhype. And the truly needle-and-drill-free future for deep cavities is still some years from the chair.

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SECTION 03

Regrowing Teeth & Gums

Two stories under one phrase: approved gum-and-bone regeneration that helps patients now, and a from-scratch tooth still in Phase 1 safety trials

”Regrowing teeth” is one phrase covering two very different stories. Coaxing gum and bone to rebuild around a tooth you still have is something approved products already do today. Growing a whole new natural tooth from scratch is real science, genuinely in human trials, and still years from your dentist’s chair. Telling those two apart is the most useful thing a reader can take from this section.

Start with the headline that has traveled the furthest. A team led by Katsu Takahashi at Kyoto University, working through the spinout Toregem Biopharma, has spent years on an antibody (now coded TRG-035) that blocks a protein called USAG-1.

USAG-1 acts like a brake on the body's tooth-building signals. Release the brake, and dormant tooth buds can develop. In mice and ferrets, blocking USAG-1 grew whole new teeth.[1]

That animal work is the proof underneath everything else, and it is worth saying plainly: it is animal work. The first-in-human trial that began in 2024 at Kitano Hospital in Osaka is a Phase 1 study. Its job is to check that the drug is safe in people. It is not designed to grow anyone a tooth. The group is small and specific: 30 healthy adult men, aged 30 to 64, each missing at least one tooth, followed for about eleven months.

> **What "in human trials" actually means here**
>
> A Phase 1 trial tests safety in a handful of carefully chosen volunteers. Whether it works in humans is still an open question. The science underneath comes from mouse and ferret data. The first medical target is a rare condition, congenital tooth absence, rather than the everyday tooth loss most adults worry about. The team's own earliest estimate for public availability is 2030, and that depends on every later trial succeeding.

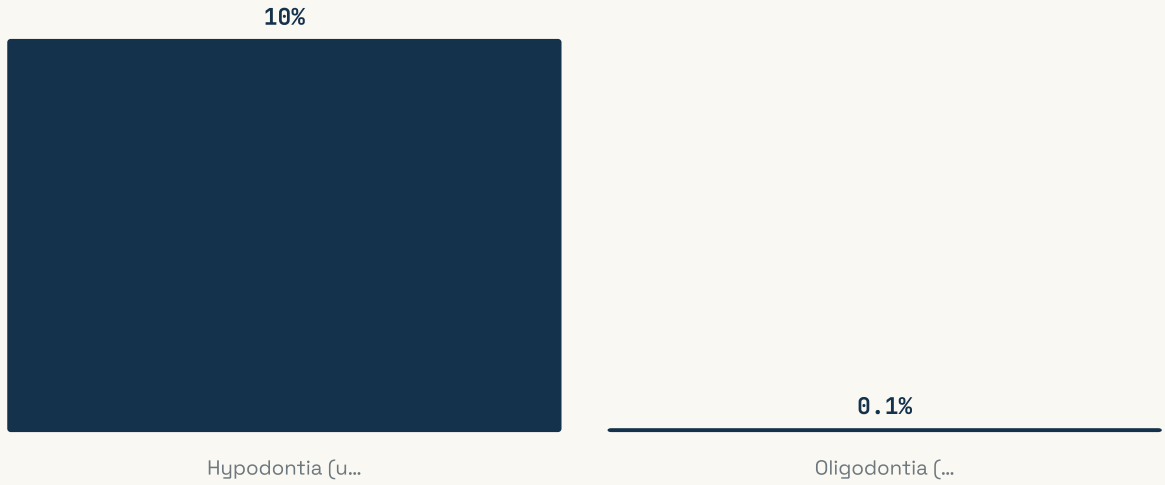
The regulatory steps so far point the same way: serious, and still early. Japan granted orphan-drug status for severe congenital tooth absence on 29 September 2025, and a US FDA pre-IND meeting followed in November 2025. Orphan status is a path built for rare diseases, which tells you who the first patients would be.[2,3]

So who is this first version even for? The target conditions are inherited, not the result of decay or a knocked-out tooth. Hypodontia, missing up to five teeth, affects about 1 in 10 people. Oligodontia, six or more missing teeth, is far rarer at roughly 1 in 1,000, and it is the first condition the drug would treat. The chart below shows how narrow that first door is.

EXHIBIT 4

How rare the first patients are

Prevalence of congenital missing-teeth conditions the tooth-regrowth drug first targets



DENTAL NATION RESEARCH

SOURCE: TAKAHASHI ET AL., JOURNAL OF ORAL BIOSCIENCE (2024)

The other "grow new tooth material" research is even earlier. At the University of Washington, stem-cell organoids were engineered in 2023 to secrete the three genuine enamel proteins (amelogenin, ameloblastin, enamelin). In 2026 the same group used an AI-designed signaling protein to mature those cells into more-mineralized enamel, confirmed on micro-CT after implantation in mice. The goal is "living fillings" that grow into a cavity and repair it. For now that goal lives on a lab bench and inside a mouse, not in any clinic.

Stem cell-derived organoids secrete tooth enamel proteins

ALGHADEER ET AL. · DEVELOPMENTAL CELL / UW MEDICINE · 2023

Lab-grown organoids made the three real enamel proteins for the first time, an early step toward growing enamel instead of drilling and filling.

7

AI-designed protein produces more-mineralized enamel

ISCRM / INTERNATIONAL JOURNAL OF ORAL SCIENCE · 2026

An AI-designed Notch-activating protein matured lab cells into harder enamel, visible on micro-CT in mice. This is animal-stage only, with no human use yet.
[8]

What can already help patients today

Now the quieter, more reliable half of the story. These are the technologies that rebuild things around or inside a tooth you already have, and several are approved and on the market.

For very early enamel damage, a self-assembling peptide called P11-4 (sold as Curodont Repair) forms a scaffold inside a tiny lesion so the mouth's own calcium and phosphate can rebuild the mineral. A 360-day randomized trial of 90 patients found real lesion regression where untreated controls only got worse. One honest limit matters: this remineralizes very early spots that have not yet become holes. It does not regrow lost enamel or fill an actual cavity.[4]

For gum disease that has eaten into the supporting bone, a recombinant growth factor (rhFGF-2, trafermin, sold in Japan as REGROTH) was approved back in 2016. Its Phase 3 evidence is the kind a new tooth drug can only hope to gather one day. The chart below shows it clearly beating placebo at rebuilding bone.

EXHIBIT 5

An approved drug that regrows gum-supporting bone

rhFGF-2 (REGROTH) Phase 3 results at 36 weeks

DENTAL NATION RESEARCH

SOURCE: PHASE 3 TRIAL, J BONE MINER RES (2016)

In a separate Phase 3 comparison, rhFGF-2 produced 1.93 mm of new linear bone growth versus 1.36 mm for enamel matrix derivative, the existing benchmark. It is a genuine regenerative drug, and it works as an aid to surgery rather than a standalone cure for advanced gum disease.[5]

Stem cells are also entering this space carefully. A 2025 multicenter trial injected donor dental-pulp stem cells into gum-disease bone defects in 132 patients (158 teeth). At six months it beat saline on attachment gain (1.67 vs 1.03 mm), pocket-depth reduction (1.81 vs 1.08 mm) and bone repair, with no serious side effects. Gum-recession improvement was not statistically significant, and the gains are measured in millimeters. The fair verdict is promising and safe, though not yet routine care.[6]

The same family of cells may even revive a tooth left dead after a root canal. A small 2017 pilot transplanted patients' own dental-pulp stem cells into five treated teeth. By four weeks, sensation returned in four of the five; by 24 weeks the MRI signal looked like normal pulp, and new dentin had formed in three. There were no adverse events, but five patients is a pilot, and the human evidence base remains very thin.

Pulp regeneration by dental pulp stem-cell transplant: a pilot study

STEM CELL RESEARCH & THERAPY · 2017

In 5 patients, dead tooth pulp showed signs of coming back to life — restored sensation, normal MRI signal, new dentin — with no side effects. Very early, and very small.

[9]

The honest takeaway

Regenerating gum and bone is here today in approved, evidence-backed products. Reviving pulp and rebuilding gum tissue with stem cells sits in early human trials, safe so far, with modest gains. Growing a brand-new tooth, the splashiest claim of all, is the least proven in humans: Phase 1 safety only, animal data underneath, a rare condition first in line, and 2030 at the very earliest. There is real reason for hope, but nothing here is around the corner.

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SECTION 04

Cavity Prevention

Cavity prevention: what is proven, what is promising, and what is still in the lab

Cavity prevention is having a quiet renaissance. New mineral pastes rebuild early enamel, a peptide gel rebuilds lesions from the inside, and a cheap liquid stops decay without a drill. All of that is real. But the foundation has not moved: fluoride is still the most thoroughly tested cavity-fighter dentistry has. The honest way to read the headlines is to ask one question of every new product. Has it been proven in people, or only promised?

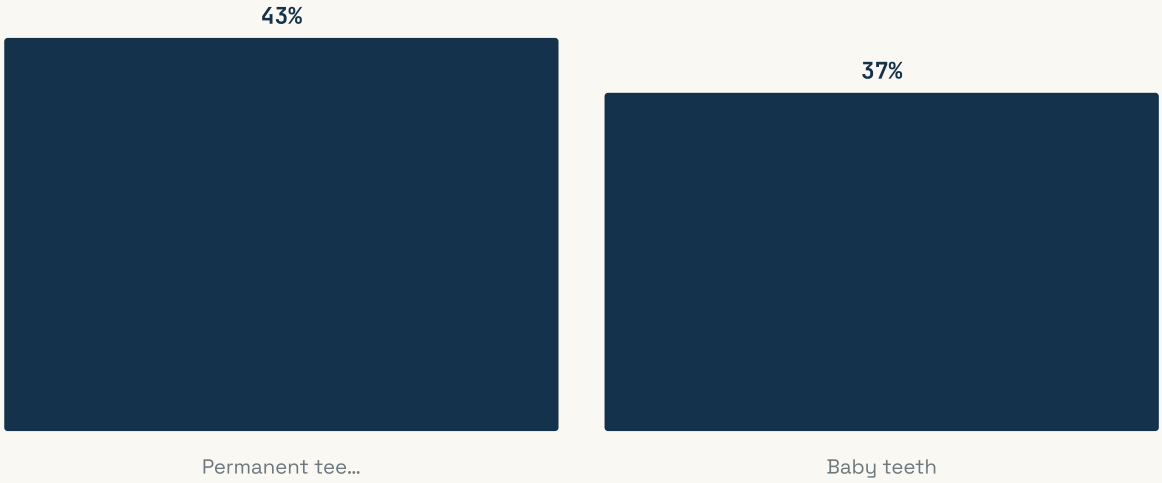
Fluoride is still the thing to beat

More than fifty years of research, pooled in Cochrane reviews covering tens of thousands of children, put fluoride toothpaste and professionally applied fluoride varnish at the top. Varnish is the clearest case. Across 22 trials and 12,455 children, it cut new cavities by about 43% in adult (permanent) teeth and about 37% in baby teeth. Every newer method on this page is measured against that bar.

EXHIBIT 6

How much fluoride varnish cuts new cavities

Pooled prevented fraction — the share of expected new cavities that did not happen



DENTAL NATION RESEARCH

SOURCE: COCHRANE REVIEW CD002279, 2013 (95% CI 30–57% PERMANENT; 24–51% PRIMARY)

The newcomers that have earned a look

Two methods have crossed from interesting to genuinely worth considering. The first is nano-hydroxyapatite, a fluoride-free mineral paste that mimics the stuff teeth are already made of. In an 18-month double-blinded trial of 189 adults, a 10% hydroxyapatite toothpaste held its own against standard 1450 ppm fluoride: 89.3% of nano-HAP users got no new cavities versus 87.4% on fluoride, with the result landing inside the pre-set "no worse than" margin. A separate 24-month trial in 610 children found a hydroxyapatite-fluoride blend turned more active early lesions in baby teeth inactive than fluoride alone. The catch worth stating plainly is that both pivotal trials were partly paid for by the toothpaste maker, so independent replication is the thing to watch.

The second is self-assembling peptide P11-4, sold as Curodont. It builds a tiny protein scaffold inside an early lesion, and the body's own saliva then refills it with mineral. A meta-analysis of six trials found it nearly doubled the rate at which early decay was stopped, with a number-needed-to-treat of under three. A 2024 trial reported 60% less progression than fluoride varnish over six months. The honest limit is that all six pooled trials carried moderate-to-high risk of bias, so the effect is real but the certainty is not yet high.

One expectation to set: both nano-HAP and P11-4 work on early lesions, the white spots and decay that has not yet broken into a hole. They rebuild thin, softened enamel. They do not fill cavities. Once there is an actual hole, you still need a filling.

Caries-preventing effect of a hydroxyapatite toothpaste in adults: an 18-month double-blinded RCT

PASZYNSKA ET AL. · FRONTIERS IN PUBLIC HEALTH · 2023

Fluoride-free 10% hydroxyapatite toothpaste was statistically non-inferior to 1450 ppm fluoride at preventing new cavities over 18 months. Funded in part by the manufacturer.

[4]

Self-assembling peptide P11-4 on arrest, cavitation, and progression of initial caries lesions

JADA META-ANALYSIS (6 TRIALS) · 2023

P11-4 (Curodont) likely produces a large increase in caries arrest versus controls (relative risk 1.82, NNT 2.8). All six pooled trials had moderate-to-high risk of bias.

[5]

[6] [7]

The underused tool: a liquid that stops decay

Silver diamine fluoride (SDF) is the quiet success of the group. It is a cheap liquid brushed onto active decay that simply stops it, no drilling. In 2024, a U.S. trial in toddlers with severe early-childhood cavities was stopped early because it was

working: decay was arrested in 54% of children on SDF versus 21% on placebo. A separate meta-analysis put SDF at roughly twice as effective as plain sodium fluoride for arresting deeper decay. One real downside keeps it from wider use: SDF permanently stains the treated cavity black, which is why it is most accepted in baby teeth and back teeth. Two points of accuracy. Arrest rates across trials vary widely, from 25% to 99%, at low-to-moderate certainty. And in the U.S. SDF is FDA-cleared for tooth sensitivity, with cavity arrest still an off-label use that the dental profession supports.

54%

DECAY ARRESTED ON SDF VS 21% ON PLACEBO (U.S. TODDLERS)

2.03×

ODDS OF ARREST VS SODIUM FLUORIDE AT 30 MONTHS

8 9 10

The frontier: fascinating, but not for the public yet

Now for the headlines to handle with care. A cavity vaccine sounds close, and the science is genuinely active: a 2025 review found anticaries vaccines cut decay risk by 47%. The detail that matters: all 17 of those studies were in animals. No cavity vaccine has ever completed a human trial or been approved. It remains, as it has for decades, "a decade away."

If you only remember one thing

None of the buzzy frontier products, the cavity vaccine, the engineered "Lumina" probiotic, or antimicrobial peptides, is backed by a completed human efficacy trial. The vaccine's 47% figure comes entirely from animal studies. The Lumina probiotic, a genetically engineered mouth bacterium sold to the public for about $250, has zero published peer-reviewed human safety or efficacy data and is branded a "cosmetic" to sidestep FDA drug review. Treat it as an unproven experiment, not a breakthrough.

[11] [12]

The same caution applies to designer antimicrobial peptides like C16G2, a "smart bomb" meant to kill only the main cavity bacterium while sparing healthy mouth flora. The idea is elegant and early data are encouraging, but development has stalled and nothing is available for cavity prevention. So here is the practical order of things: fluoride toothpaste and varnish for everyone; nano-HAP and P11-4 worth trying on early lesions; SDF an underused way to stop decay if you can accept the staining; and vaccines, engineered probiotics, and peptides still firmly in the lab.[1]

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SECTION 05

Stronger, Longer-Lasting Fixes

Proven crowns and implants are here now; self-healing and regenerative fillings are mostly still in the lab

Here is some good news that rarely makes headlines: the repairs your dentist places today already last a long time. The next wave of materials wants to push that further, and some of it is genuinely arriving. The distance between what works in a clinic and what works in a press release is wide right now, so it helps to sort the proven from the promising.

The clearest wins are in crowns and implants. A crown used to be a hard ceramic core with a thin layer of tooth-colored porcelain baked on top, and that porcelain layer was the weak point. It chipped. Newer crowns are carved from a single solid block of zirconia, with no veneer to break off. That one change shows up plainly in the long-term numbers.

EXHIBIT 7

Single-block crowns outlast the older veneered kind

Cumulative survival, monolithic (solid) zirconia vs porcelain-fused or layered zirconia

DENTAL NATION RESEARCH

SOURCE: J PROSTHET DENT 2025; MEDICINA 2025

In the five-year study, most of the failures that did happen were the porcelain chipping off the layered crowns. Take away the veneer and you take away the most common way these things break. If you are getting a back-tooth crown, it is a fair question to ask your dentist for the solid single-block version.[1,2]

Implants hold up like joint replacements

Dental implants are now old enough to have twenty-year records, and the records are reassuring. A 2024 meta-analysis put twenty-year survival at roughly 88 to 92 percent, dropping to about 78 percent once you account, statistically, for patients who stopped coming in. Call it four out of five implants still working two decades later. The authors note that is on par with knee replacements (around 82 percent at 25 years) and better than many hip replacements.

> ### An implant is a long-term investment that needs upkeep
>
> Late failures usually trace back to gum disease, diabetes, smoking, and older age, which roughly double the risk. The implant lasts when it gets lifelong maintenance, and tends to fail when that maintenance is skipped.

[5]

Digital dentures: a real workflow win

Dentures designed on a computer and then milled or 3D-printed are in clinics today, not on the horizon. They cut chair time, and because the design lives in a file, a lost or broken denture can be reprinted from the saved version. That is a genuine convenience. What the head-to-head evidence has yet to show is a leap in how they feel. A 2024 review found no meaningful difference between milled and printed dentures on retention or patient satisfaction. The advance so far is in how these dentures are made, and the comfort numbers have not moved much yet.[3]

The "smart filling" hype, weighed honestly

This is where the marketing runs ahead of the proof. ”Bioactive” fillings are sold as cavity-fighting upgrades that release fluoride and calcium to protect the tooth. They do release those minerals. The trouble is the outcome that actually matters: do they stop the secondary cavities that creep in at the edge of a filling and cause most failures? The best 2025 evidence says, so far, they do no better than an ordinary filling.

Bioactive resin materials for preventing secondary caries and retention loss

SYSTEMATIC REVIEW AND META-ANALYSIS · JOURNAL OF DENTISTRY · 2025

Across 10 randomized trials and 411 patients (followed up to 8 years), commercial bioactive composites (ACTIVA, giomer, Cention N) showed no statistically significant advantage over conventional composite at preventing secondary caries or holding on ($p>0.05$).
[6]

The verdict is not closed, to be fair. A separate 2023 network analysis in BMC Oral Health did find differences between material types, though it rated its own certainty as only low to moderate, and several new trials finish in 2026 and 2027. So the answer may shift. For now, treat ”self-healing filling” claims with friendly skepticism.[4]

The truly clever chemistry is real, and for now it lives in the lab. One approach packs tiny capsules into the filling that burst and release a healing agent when a crack forms, recovering 25 to 80 percent of the material’s toughness. A newer approach is stranger and quite striking: dormant bacteria seeded into the composite wake up inside a crack and lay down calcium carbonate to wall it off, repairing up to 85.8 percent of the damage in a dish over 60 days. Both are laboratory-stage. Neither is in anyone’s mouth.

A self-healing dental composite using bacteria-induced biomineralization

FRONTIERS IN BIOENGINEERING AND BIOTECHNOLOGY · 2025

Dormant bacteria embedded in the resin reactivate inside a crack and deposit mineral, sealing up to 85.8% of artificial scratch and crack area in vitro over 60 days. Strictly laboratory stage, no clinical trials.
7

Microcapsule-based self-healing dental composites: a review

JOURNAL OF FUNCTIONAL BIOMATERIALS (MDPI) · 2024

Capsules that rupture and release a repair agent restore between 25% and 80% of original fracture toughness in lab testing. The capacity is limited, some toxicity questions remain, and nothing is commercialized.
8

The frontier: growing the tooth back instead of patching it

The most futuristic work tries to regrow enamel and dentin rather than fill them with synthetic material, and some of it has crossed into human territory. A protein gel from the University of Nottingham, reported in Nature Communications in late 2025, coaxes saliva's own calcium and phosphate into rebuilding enamel-like mineral, with a startup aiming for a first product around 2026. A drug-based method to regrow dentin is in human trials, and a tooth-regrowth drug from a Kyoto team entered its first human trials in 2024.

On the horizon, not at the chairside

That tooth-regrowth drug is real and remarkable, but "close to being available" overstates it. The general-use target is roughly 2030 at the earliest, it depends on the trials succeeding, and the first patients would be children with a rare congenital condition rather than the average adult missing a tooth.

9 10

So the honest summary splits cleanly in two. The "stronger" part of the story, the crowns, the implants, the digital workflows, is here now and backed by real long-term data. The "self-healing and biological" part is exciting and moving fast, and most of it still sits in the lab or in early trials. Both are worth being hopeful about. Only one of them is something you can ask for at your next appointment.

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SECTION 06

Whiter, Better Smiles

The gentler the whitening and the thinner the veneer, the more of your real tooth survives

For decades, a whiter smile meant one thing: peroxide. It still works. But scientists can now measure exactly what it costs your enamel, and that careful accounting is pushing the whole field toward something gentler. Newer whiteners promise the same brightness with far less sting, and veneers are getting so thin that a dramatic makeover can leave almost all of your real tooth intact.

Start with the chemistry most of us already know. Hydrogen and carbamide peroxide reliably lighten teeth, and there is no argument about that. The catch is sensitivity. In the clinical literature, the prevalence of tooth sensitivity during in-office bleaching

runs above 87 percent of patients. That twinge with cold water is the common experience, not rare bad luck. Peroxide also measurably softens enamel while it works, and one 2026 lab comparison clocked the surface hardness loss at roughly 47 to 77 Vickers units depending on the agent.[1]

None of this means whitening is dangerous. It means it has a price, and the most hopeful work in cosmetic dentistry is about lowering that price. The first gentler choice is already on the shelf: carbamide peroxide. A 2024 systematic review of three randomized trials found that 37 percent carbamide peroxide reaches a color change similar to 35 percent hydrogen peroxide after three or more sessions, while causing significantly less sensitivity. The footnote worth keeping in mind is that the certainty was low for how well it whitens and moderate for the sensitivity benefit.[2]

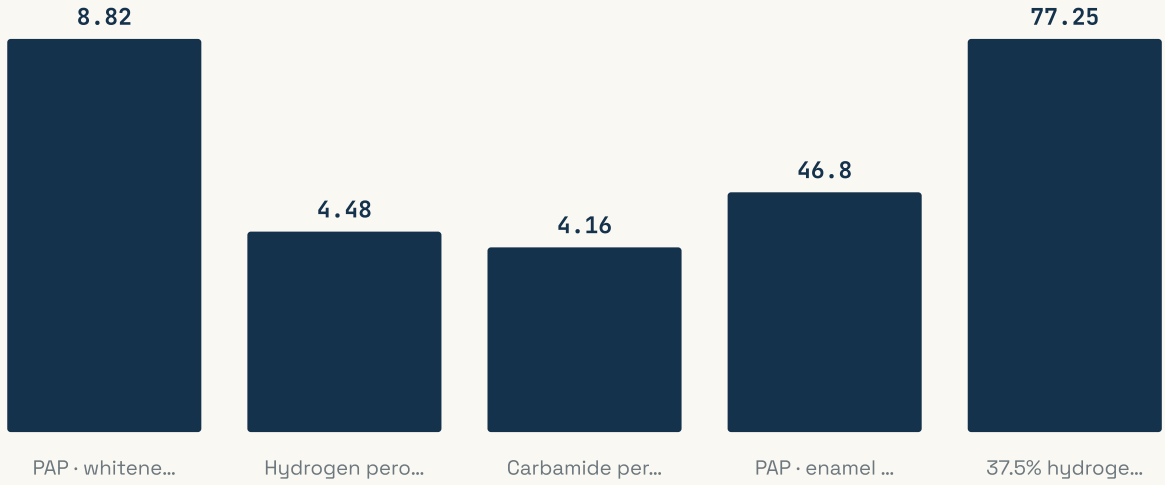
The peroxide-free contenders

The more interesting frontier skips peroxide entirely. The leading candidate is a mouthful called PAP (phthalimidoperoxycaproic acid). In a 2026 lab study, PAP actually out-whitened both peroxides while being kinder to enamel and producing no free radicals, with reported sensitivity near zero. Two cautions matter here. This is in-vitro work, with as few as four samples per group for the hardness measurements, and there are still no large clinical trials pitting PAP against high-strength professional peroxide, which remains the real gold standard. PAP is genuinely promising. It is not yet proven the way peroxide is.

EXHIBIT 8

PAP whitened more, with less enamel damage (in vitro)

Whiteness index change (higher is whiter) and enamel hardness loss (lower is gentler), 2026 lab study



DENTAL NATION RESEARCH

SOURCE: PHTHALIMIDOPEROXYCAPROIC ACID (PAP) VERSUS PEROXIDES, J. FUNCT. BIOMATER. 2026

7

There is also a quieter, lower-risk route aimed largely at younger users: violet-pigment "color correctors" and nano-hydroxyapatite. A 2025 review found these deliver a mean color change of about 3.1 on the delta-E00 scale, which sits right around the threshold where a change becomes noticeable, with sensitivity under 3 percent and no detected enamel erosion. The effect is mild. The trade is that it asks very little of your enamel.[3]

Veneers that keep your tooth

Whitening only goes so far. For a bigger change, the news is about preservation. Ultra-thin porcelain veneers, some as slim as 0.2 to 0.5 mm, can reshape a smile while removing almost none of the natural tooth. In a nine-year prospective study, no-prep and minimally invasive veneers showed 100 percent survival, against just 9.67 percent absolute survival for conventionally prepped veneers in the same patients. That

headline is striking, and it deserves its asterisk: it comes from a single 35-patient study where one operator did both kinds. It strongly supports the idea of bonding to enamel and cutting away as little as possible, but it is one study, not a settled body of trials.

The broader durability picture is reassuring. A 2024 meta-analysis covering 7,753 restorations across 986 patients put 10-year survival for lithium disilicate veneers at 96.81 percent, with debonding around 2.2 percent and secondary decay near 2.83 percent. One practical detail for choosing materials: lithium disilicate had a far lower technical complication rate than feldspathic porcelain (6.1 percent versus 41.48 percent), so the prettiest ultra-thin option and the most trouble-free option can pull in slightly different directions.

VENEER APPROACH	SURVIVAL	KEY CAVEAT
No-prep / minimal-prep feldspathic	100% at ~9 yrs	Single 35-patient study
Lithium disilicate (pooled)	96.81% at 10 yrs	Strongest evidence base
Ultra-thin no-prep zirconia	99.5% at 2 yrs	Follow-up still short

8 9 10

Designing your smile before anyone touches a tooth

One more shift makes all of this less of a leap of faith. Digital Smile Design lets you and your dentist plan and preview a new smile in 3D first. The leading software scores well on standard usability tests, with SmileCloud at 80.33 against a 68-point benchmark, which mostly means the tools are easy enough to actually use in a real appointment.[4]

Artificial intelligence is now drafting these designs too, and here the candid answer matters. AI works best as a fast first draft and a communication aid rather than the final aesthetic verdict. In a 2025 study of 320 people, including dentists, 60 to 69 percent preferred the human-crafted smile over the AI-generated one across every

case. A separate meta-analysis pooled patient satisfaction with AI designs at 58 percent, with high variation between studies. The artist still wins, for now.[5,6]

The through-line: protect the enamel

Every advance here points the same way. Gentler whiteners exist because peroxide costs enamel hardness. The best veneers survive because they bond to enamel and remove almost none of it. The honest version of progress is not a stronger kit bought online. Regulators cap cosmetic hydrogen peroxide at 6 percent for professional use in the EU, and the ADA considers 3.5 percent or less generally safe over the counter. The whitest, most beautiful smile is increasingly the one that sacrifices the least of your real tooth.

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SECTION 07

Oral Health & Your Whole Body

How gum health connects to the heart, blood sugar, brain and pregnancy — what the 2024-2025 evidence actually supports

Your mouth is not a sealed-off room. The same low-grade inflammation and bacteria behind gum disease can travel and signal through the rest of the body, and a wall of 2024-2025 research now ties poor oral health to the heart, blood sugar, brain, and pregnancy. The honest headline first: most of these are strong associations, not yet proven cause and effect. The good news is just as real. Gum disease is largely preventable, treatment reliably lowers inflammation in the blood, and for people with diabetes it can move blood sugar about as much as a second medication.

One thread connects almost every story in this section: chronic low-grade inflammation. Diseased gums keep inflammatory messengers like C-reactive protein, IL-6 and TNF circulating, and cleaning the gums measurably brings them down. That single idea links the heart, diabetes and brain findings without overclaiming any of them.

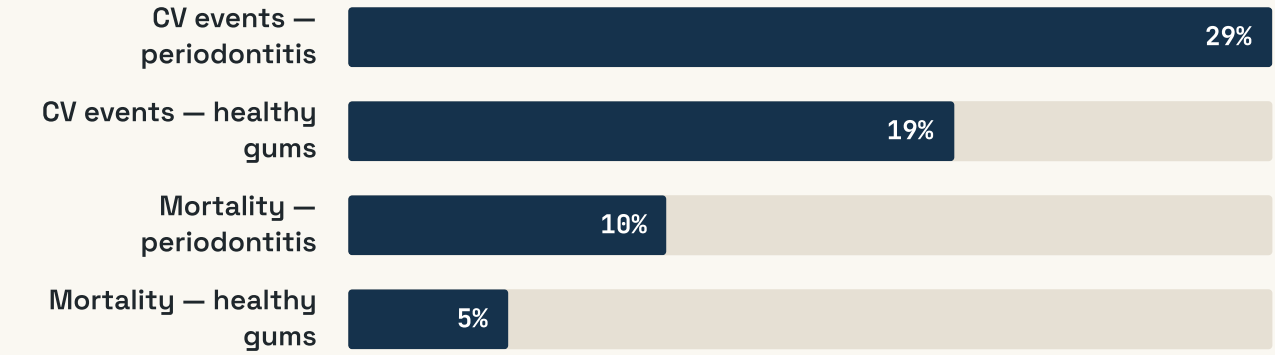
The heart: a real link, an honest limit

Gum disease (periodontitis) affects more than 40% of U.S. adults over 30, and it travels with cardiovascular risk. The PAROKRANK study followed 1,587 people for roughly ten years and found cardiovascular events in 29% of those with periodontitis versus 19% of people with healthy gums. After adjusting for age, smoking and diabetes, the hazard ratio was 1.26. Death rates were 10% versus 5%.

EXHIBIT 9

Periodontitis and the heart, over a decade

PAROKRANK: 1,587 people followed a mean of 9.9 years. Association, not proof of cause.



DENTAL NATION RESEARCH

SOURCE: J CLIN PERIODONTOL, PAROKRANK FOLLOW-UP, 2024 (ADJUSTED HR 1.26, 95% CI 1.01-1.57)

6

Here is the part worth being careful about. The American Heart Association's December 2025 scientific statement confirms an independent association and a plausible mechanism, but says plainly that a cause-and-effect relationship has not been confirmed, and that there is no direct evidence yet that treating gum disease prevents heart disease. What treatment does reliably do is lower inflammatory markers tied to heart risk, including CRP, fibrinogen and white blood cell count.

Read this carefully

"Gum disease is associated with heart disease" is supported. "Treating gum disease prevents heart attacks" is not. The AHA itself draws that line. Brush and floss because the downside is essentially zero and the upside may be large, not because anyone has proven it stops a heart attack.

7

Diabetes: the clearest payoff

This is the strongest two-way street in the whole section. People with diabetes get more gum disease, and gum disease worsens blood-sugar control. Between 20% and 40% of people who turn up with periodontal disease are found to have diabetes or pre-diabetes. And treating the gums measurably lowers blood sugar. A 2025 meta-analysis of 11 randomized trials found deep cleaning lowered HbA1c by 0.64 percentage points at three months and 0.33 at six months. For context, starting metformin improves HbA1c by roughly 0.56 points.

-0.64	~0.56	~3×
HBA1C POINTS, 3 MONTHS AFTER GUM TREATMENT	HBA1C POINTS FROM STARTING METFORMIN	RISE IN DIABETIC COMPLICATIONS PER 1% HIGHER HBA1C

8 9

Because every 1% rise in HbA1c is linked to roughly a threefold jump in diabetic complications, even a modest gum-treatment gain matters. This is the cleanest "your dentist can help your whole body" story we have: a measurable drop in blood sugar, no new prescription.

The brain: promising, not proven

Tooth loss tracks with cognitive decline. A meta-analysis pooling cohort studies across 356,297 people found tooth loss linked to about 15% higher dementia risk and 20% higher risk of cognitive decline. A 2025 CDC study of 83,479 U.S. adults found that middle-aged people who had lost six or more teeth had nearly double the rate of subjective cognitive decline, while a dental visit in the past year tracked with lower odds.

Tooth loss and the risk of cognitive decline and dementia: a meta-analysis of cohort studies

FRONTIERS IN NEUROLOGY · 356,297 PARTICIPANTS · 2023

Pooled tooth loss was linked to a 15% higher dementia risk and a 20% higher cognitive-decline risk. Observational, so it cannot prove cause.

10

The Impact of Oral Health and Dental Services on Subjective Cognitive Decline in Middle-Aged and Older US Adults

CDC, PREVENTING CHRONIC DISEASE · 83,479 ADULTS · 2025

Adults 45-64 who lost 6+ teeth had a 1.91 prevalence ratio for cognitive complaints; a recent dental visit tracked with lower odds (PR 0.77). SCD was 13.6% with poor oral health versus 7.7% with good.

11

There is a tempting mechanism here. The gum bacterium *Porphyromonas gingivalis* and its toxic gingipain enzymes have been found in Alzheimer's brains and can drive amyloid and tau changes in lab studies.[1]

But the 2024 Lancet Commission on dementia declined to list oral health as a confirmed risk factor, because the evidence was not strong enough. And these tooth-loss findings are observational, so healthier, more health-engaged people may both keep their teeth and stay sharp for other reasons. Encouraging. Not settled.[2]

Pregnancy: timing changes the message

Gum disease is clearly associated with preterm birth and low birth weight, with odds ratios ranging from about 2 to 4 across studies. But the honest, slightly counterintuitive finding is that treating gum disease during pregnancy does not reduce preterm birth (relative risk 0.90, not significant) or low birth weight. The lesson points to gum health before and between pregnancies, not a mid-pregnancy rescue.[3]

The hopeful frontier: spit as a window

The most forward-looking story is saliva. Researchers are building salivary tests that could flag diabetes, heart disease and neurological conditions early, turning a routine dental visit into a checkpoint for the whole body. The field is moving fast, with roughly 300 salivary-diagnostics and 600+ oral-microbiome studies on PubMed in 2024 alone, a two-to-sixfold jump since 2014. Researchers have even shown mouth bacteria can reach distant tissue: a specific *Fusobacterium nucleatum* subtype was enriched in about half of colorectal tumors in one 2024 study.[4,5]

What you can actually do

Brush twice a day (three is better), floss, and keep regular dental visits. Unlike your genes, gum health is cheap to protect and fully in your hands. The causal questions are still being worked out, but this is one of the few longevity levers with almost no downside and a real chance of paying off beyond your smile.

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Advances for Kids

How children's cavities are being treated as a disease to control, not a hole to drill

For most of the last century, fixing a child's cavity meant a drill, a needle, and a scared kid in the chair. Sometimes it meant general anesthesia. That model is being taken apart, piece by piece. A child can now have an active cavity stopped with a painless liquid painted on the tooth, get a baby molar crowned without any drilling, and be screened for early decay through a smartphone photo. The shift underneath all of it is a change in thinking: tooth decay in kids is being treated as a disease to control, not a hole to drill.

This matters because decay is still the most common chronic disease of childhood, more common than asthma. Early childhood caries affects close to half of

preschoolers worldwide, and the burden falls hardest on kids who have the least access to care.

~48-49%
OF PRESCHOOLERS WORLDWIDE AFFECTED BY EARLY CHILDHOOD CARIES

573M
CHILDREN WITH UNTREATED DECAY GLOBALLY

~72%
PREVALENCE IN THE MIDDLE EAST, THE HIGHEST REGION

The headline advance: a liquid that stops cavities

The single most transformative tool here is silver diamine fluoride, usually shortened to SDF. It is a liquid a dentist brushes onto a decayed baby tooth. No drill, no needle, no numbing. A 2024 systematic review found that the 38% concentration arrested about 81% of active cavities in primary teeth. Across the wider literature, reported arrest rates swing from 25% to 99%, which is honest evidence that results vary a lot by tooth, surface, and study.

EXHIBIT 10

What SDF actually does to a baby-tooth cavity

Share of active cavities arrested in primary teeth, by the headline study and the full evidence range

38% SDF, 2024 review	~81%
Range, low end	25%
Range, high end	99%

DENTAL NATION RESEARCH

SOURCE: MDPI CHILDREN SYSTEMATIC REVIEW (2024); FRONTIERS IN ORAL HEALTH META-ANALYSIS (2024)

7 8

There is a real catch, and parents need to hear it up front. SDF permanently turns the arrested cavity black. It is a cosmetic trade for skipping the drill, and it usually needs reapplying to keep the decay stopped. One coat is rarely a permanent fix. There is also a regulatory detail worth getting right, because it gets muddled often: the FDA first cleared SDF in 2014 as a device for tooth sensitivity, then in 2016 granted it Breakthrough Therapy designation specifically for arresting decay in children. Two different milestones.

> **The honest version**
>
> SDF is cheap, painless, and works well enough to belong in school and low-resource settings where a drill and a dental chair often are not available. It also stains the cavity black and usually needs a repeat visit. Both things are true at once, which is exactly why dentists ask parents to consent to the look before they paint it on.

9 10

Prevention that already works, just underused

Two old, proven tools are still doing most of the quiet good. Dental sealants are a thin coating painted over the grooves of back teeth, which is where about 9 in 10 childhood cavities start. The CDC says sealants prevent roughly 80% of those cavities over two years, and that children without them get nearly three times more first-molar cavities. Yet only about 42% of US kids aged 6 to 11 have them, and the gap tracks family income. Sealing around 7 million low-income children could save up to $300 million in treatment costs.

Fluoride varnish is the other workhorse, brushed on two to four times a year. A Cochrane review of 22 trials covering 12,455 children found it cut decayed, missing, and filled surfaces by about 43% in permanent teeth and 37% in baby teeth. That evidence is rated moderate, not definitive, because of study bias and variation between trials.[1,2]

The drill is becoming optional

When a cavity is too far gone for varnish, the chair is changing too. The Hall Technique slips a small metal crown over a decayed baby molar with no drilling and no numbing. One RCT in high-caries-risk children reported 94.2% success at one year. An earlier landmark trial in general practice followed 132 children for 23 months and found Hall crowns had major failures in only 2% of teeth, against 15% for conventional

drill-and-fill. SMART, which pairs SDF with a glass-ionomer filling, performs comparably to standard treatment, costs less, and is better accepted by children.

APPROACH	RESULT IN BABY MOLARS	STUDY
Hall crown success at 1 year	94.2% (high-risk kids)	Nigerian J Clinical Practice RCT (2021)
Hall vs conventional major failures	2% vs 15% at 23 months	BMC Oral Health RCT (2007)
SMART vs standard restoration	Comparable survival, lower cost	Journal of Dentistry RCT (2022)

[11] [12] [13]

Taking the fear out, with evidence

The deepest change may be the least technical. Tell-show-do, the practice of explaining and demonstrating before treating, is well established for calming anxious children. A 2025 RCT of 42 highly anxious kids aged 5 to 10 found that adding an AI-animated explainer video to tell-show-do lowered anxiety scores more than tell-show-do alone. And because Hall crowns, SMART, and SDF avoid the needle and drill in the first place, fewer children pile up the scary experiences that grow into lifelong dental phobia. That heads off the fear instead of managing it later.[3]

One frontier deserves a careful note. AI tools that spot cavities on images report individual accuracies between 73% and 99%, with pooled specificity around 88%, and smartphone apps such as AICaries aim to screen children who cannot reach a dentist. The honest read: the studies vary enormously, and almost none have been validated specifically on children or baby teeth yet. It is promising for widening access to early screening, not a proven pediatric diagnostic.[4,5]

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SECTION 09

On the Horizon

From peptide enamel repair to a 2030 tooth-regrowth drug: sorting real progress from the hype

For a century, fixing a tooth has meant the same thing: drill out the damage and patch it with metal, resin, or ceramic. The most exciting research in dentistry asks a different question. What if the body could repair or regrow its own tooth instead? Several teams are chasing that idea, but they sit at wildly different stages, and being honest about the gap between them matters more than the headlines suggest.

The cleanest way to read this field is in three tiers: technology that is already in clinics, technology that has reached human bodies but is still early, and technology that lives only in a lab dish. Lumping these together is how a careful breakthrough gets oversold.

29
FDA-CLEARED DENTAL IMAGING AI PRODUCTS (≈13 COMPANIES)

30
MEN IN THE FIRST HUMAN TOOTH-REGROWTH SAFETY TRIAL

0 / 17
CAVITY-VACCINE STUDIES DONE IN HUMANS

Here now: peptides and AI

The closest thing to clinical reality is not a regrown tooth at all. It is a peptide. Self-assembling peptide P11-4, sold as Curodont Repair, seeps into an early lesion and builds a tiny scaffold that coaxes the tooth's own calcium and phosphate to lay down new mineral. Several randomized trials back it up. In one 2020 trial, every treated lesion went inactive (56 of 56) against just 13 of 23 in the control group. A 2018 trial put the odds of inactivating a lesion at 12.2 times higher than fluoride

alone. There is one hard limit to keep in front of patients: this works on early, non-cavitated white-spot lesions. It cannot fill a hole that already exists, so it sits alongside fillings rather than replacing them.[1]

The other thing already in clinics is software, not biology. Roughly 29 FDA-cleared AI tools now read dental X-rays for signs of decay, and pooled results put their sensitivity around 0.85 and specificity around 0.90. The popular framing needs a caution, though. What the evidence supports most clearly is that AI helps dentists beat their own baseline, catching more early lesions that the unaided eye tends to miss. That is a different and more defensible claim than saying the software outperforms a clinician outright. Accuracy also swings depending on the image type, so a number on a bitewing is not the same as a number on a panoramic.[2,3]

In humans, but early: the tooth-regrowth drug

This is the one everyone has heard about. A Japanese team developed an antibody, TRG-035, that blocks a protein called USAG-1. USAG-1 normally puts a brake on tooth growth, and releasing that brake let mice grow whole new teeth. In autumn 2024 the drug entered its first human trial at Kitano Hospital in Osaka. Read the fine print carefully: it is a Phase I trial in about 30 adult men, aged 30 to 64, each missing at least one tooth, over roughly 11 months. Its job is to check that the drug is safe, not to prove it grows teeth in people. The team's stated goal of public availability "by 2030" is a hope, not a schedule, and it would first target a rare congenital condition in children, not routine tooth loss.[4]

The animal work shows why caution is warranted. In mice, a single dose reversed missing-tooth conditions at a high rate. In ferrets it also worked, but only at five times the dose, given three times, plus immunosuppression. That jump is a real signal that translating to humans is far from guaranteed.[5]

Still in the lab: organoids and the cavity vaccine

Two strands are genuinely promising and genuinely not ready. They sit on the laboratory bench, and presenting them as near-term would be a mistake.

Generating Tooth Organoids Using Defined Bioorthogonally Cross-Linked Hydrogels

ZHANG ET AL. · ACS MACRO LETTERS · 2024

Researchers at King's College London and Imperial College London grew early-stage "tooth organoids" in a custom hydrogel that drip-feeds developmental signals over time. Every experiment used mouse-embryo cells in a dish. The authors are clear that clinical use is years away.

8

Efficacy and Immunogenicity of Anticaries Vaccines: A Systematic Review and Meta-Analysis

IMMUNITY, INFLAMMATION AND DISEASE · 2025

Across 17 studies, a cavity vaccine cut caries risk by a pooled 47% (risk ratio 0.53). The catch is decisive: all 17 studies were in animals. No anticaries vaccine has ever reached a human trial or won approval, a 50-year reminder that dramatic animal results are not the finish line.

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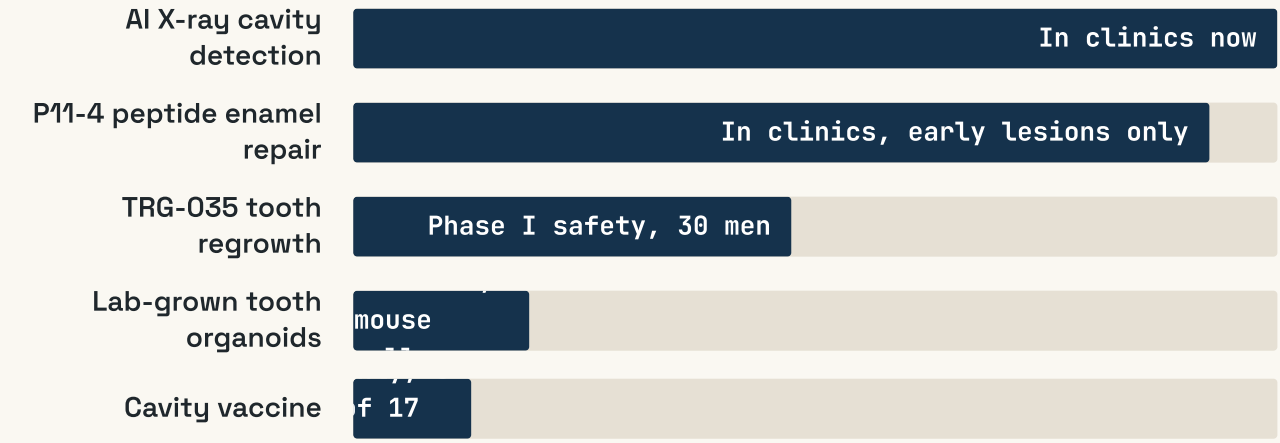
EXHIBIT 11

Maturity ladder: how far each idea has actually come

Higher bar means further along the road from lab dish to dental chair.



DENTAL NATION RESEARCH

SOURCE: MEDPATH (2024); SCIENCE ADVANCES (2021); ACS MACRO LETTERS (2024); IMMUNITY, INFLAMMATION AND DISEASE (2025); INNOLITICS (2025)

A few quieter threads round out the picture. Dental-pulp regeneration through "cell homing," which recruits the body's own stem cells with scaffolds and signals, already underpins approved revascularization and pulp-capping procedures, making it the most clinically grounded of the regenerative routes. And a new class of "smart" fillings that release calcium-phosphate or antibacterial nanoparticles is being studied, though that work is mostly laboratory-stage, and vendor claims of imminent availability deserve a skeptical read.[6,7]

The honest bottom line

Peptide enamel repair and AI X-ray reading are here, working, and already in some chairs. A real tooth-regrowth drug is genuinely in human testing, which is remarkable, but it is a safety trial and 2030 is a best case, not a promise. Lab-grown teeth and the cavity vaccine are exciting science that has not yet earned a place in the clinic. For now, none of this replaces the filling or the implant. It points to a future where, with luck and time, fewer people will need them.

SOURCES

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4. Japanese Researchers Begin Human Trials for Tooth Regeneration Drug, Medpath (2024) — trial.medpath.com
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6. Regenerative endodontic therapy: from bench to clinic, PMC (2025) — pmc.ncbi.nlm.nih.gov
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About this report

Researched against peer-reviewed journals, Cochrane, the ADA, NHS, FDI World Dental Federation and named industry sources via the Dental Nation deep-research engine, with the contentious claims independently fact-checked. Source numbers in the text correspond to the Sources list at the foot of each section.

General educational information, not personalised medical advice.

Dental Nation Research
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