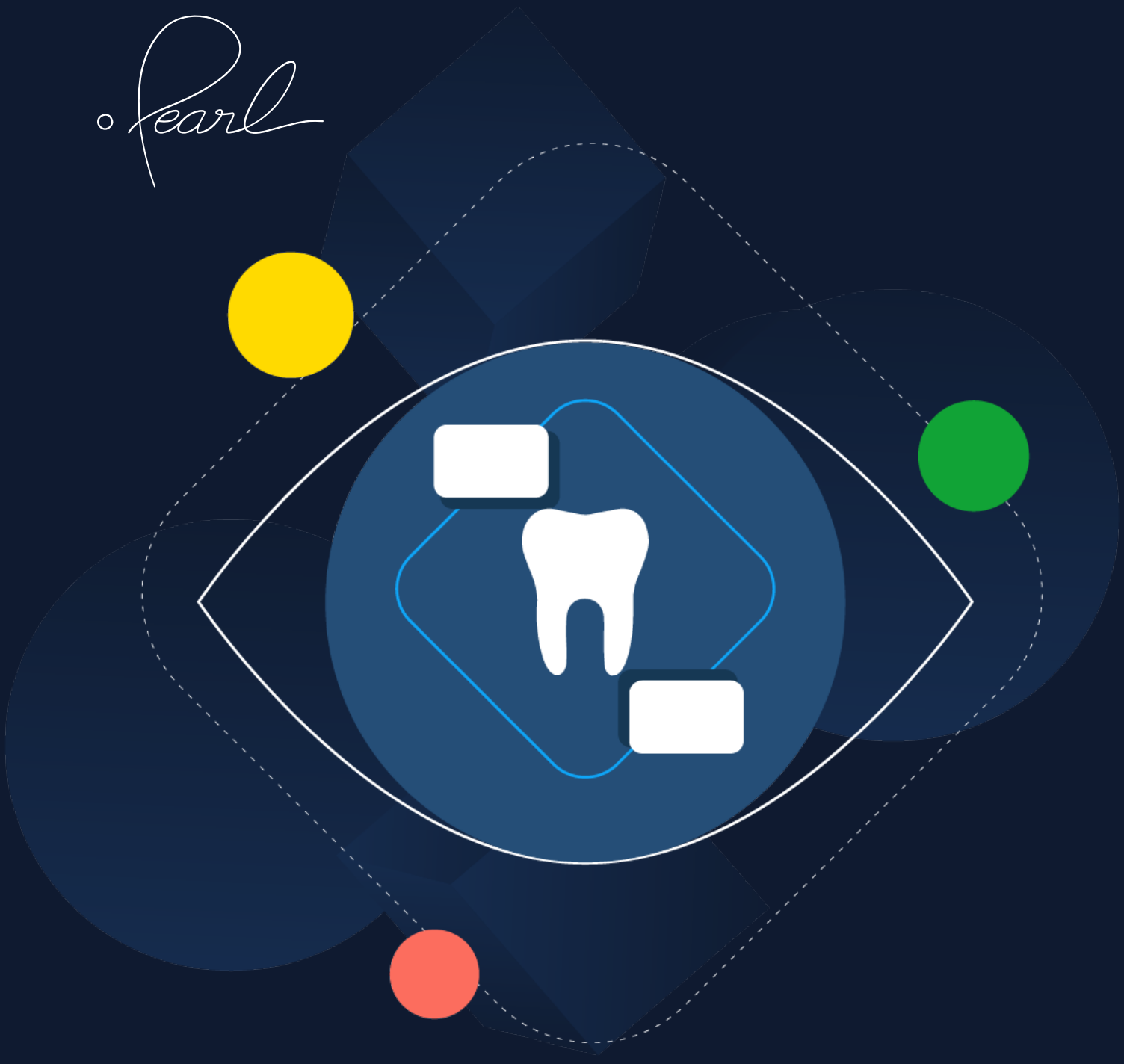
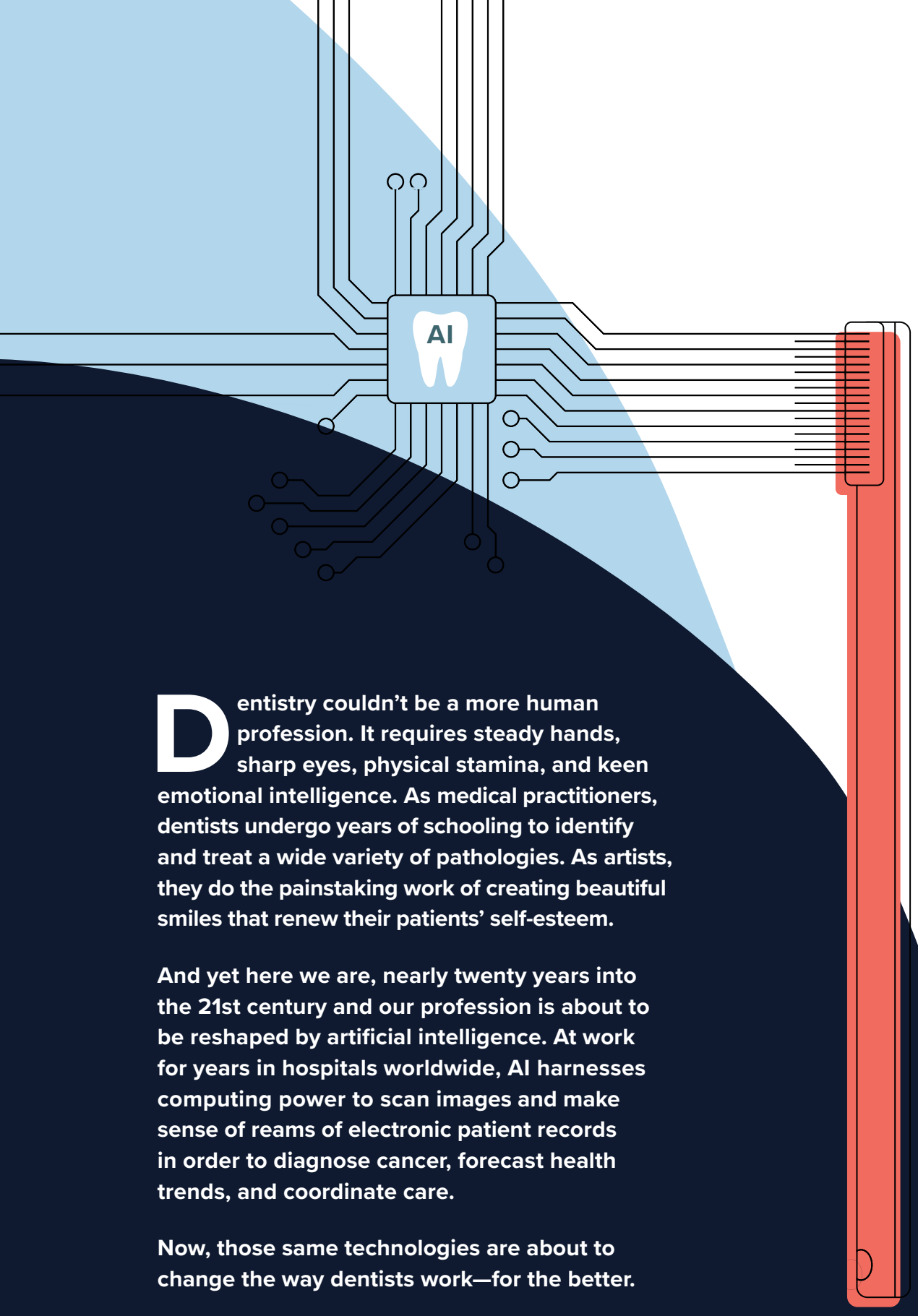
Pearl



# THE FUTURE OF DENTISTRY, POWERED BY AI




Dentistry couldn't be a more human profession. It requires steady hands, sharp eyes, physical stamina, and keen emotional intelligence. As medical practitioners, dentists undergo years of schooling to identify and treat a wide variety of pathologies. As artists, they do the painstaking work of creating beautiful smiles that renew their patients' self-esteem.

And yet here we are, nearly twenty years into the 21st century and our profession is about to be reshaped by artificial intelligence. At work for years in hospitals worldwide, AI harnesses computing power to scan images and make sense of reams of electronic patient records in order to diagnose cancer, forecast health trends, and coordinate care.

Now, those same technologies are about to change the way dentists work—for the better.

# What is artificial intelligence?

AI has gotten a bad rap in pop culture. It's been sent from the future. It won't open the pod bay doors. That sci-fi AI is what's known as "artificial general intelligence"––computer intelligence indistinguishable from human intelligence––and it remains very much a fantasy.

The AI that everyone is talking about today is much friendlier.

Scientists call it "narrow AI". That's because it's very good at performing highly specific, repetitive tasks––busywork like dictation, scheduling, sorting, labeling, and route planning that once took up about 30 percent of our workday. AI is now giving us back that time––and so much more.

When you break it down, AI is simply a set of algorithms that work together to accomplish goals set by humans. Computer scientists "train" these algorithms by feeding them troves of data––a process called "machine learning." The algorithms learn to recognize patterns in information, which ultimately allows the AI to accurately categorize and make predictions about how we show it.

Over the past 10 years, a wide variety of artificial intelligence has made its way into our lives. Natural language processing powers voice assistants like Siri and Alexa. Google Maps uses predictive analytics to determine how long our commute will be. Computer vision reads the license plates of speeding drivers. There is, in fact, practically no facet of modern life that is not now or will not soon be touched by AI in some way.

That includes medicine, where AI is already delivering on some of its life-saving potential. In hospitals, for example, AI-powered technologies have been deployed to identify abnormalities in brain, heart, and lung scans with superhuman speed and precision. As early as 2011, researchers from NYU Langone Health found that computer vision could find specific lung nodules between 62% to 97% faster than a panel of radiologists.

**It's no surprise then that dentistry is AI's next frontier.**

Dentists can now harness the power of AI using Pearl, a computer vision platform that scans and annotates dental imagery, identifying dozens of pathologies like tooth decay, open margins, and bone loss, as well as past dental work. Pearl, founded by computer vision veteran Ophir Tanz and Dentist and opinion leader Dr. Kyle Stanley, trained its AI on millions of anonymized X-rays and medical records annotated by expert dentists around the globe. The system also uses natural language processing and predictive analytics to scan patient histories and medical records to find trends, predict progressions, and chart treatment plans. Taken together, Pearl's AI software solutions will have a dramatic impact on the day-to-day operations of dental offices around the world.

# Tell AI where it hurts

The future of dentistry is bright. The number of dental school graduates is on the rise. Job growth will continue through 2062. And the median income is holding steady at more than $150,000, according to the Bureau of Labor Statistics. In fact, dentistry was ranked the fourth best job in America this year by U.S. News and World Report.

But there are still tender spots. Dentistry is a high-stress, high-risk profession: Dentists often work with patients who fear their treatments, they worry about being sued and they carry tremendous financial burdens. AI won't completely eliminate these concerns, but it can provide valuable support to help dentists focus on what they do best: providing expert—human—care.

"With the right algorithms, you start seeing all kinds of new opportunities."

**To help you better understand what kind of artificial intelligence is at work and where, we've put together a short list of terms you'll need to know at the next cocktail party.**

### COMPUTER VISION

AI that can see and analyze visual data and then make decisions about it. Computer vision is used in facial recognition technology, self-driving cars, and other software that processes imagery.

### MACHINE LEARNING

Machine learning algorithms detect patterns and learn how to make predictions and recommendations by processing data and experiences, rather than by receiving explicit programming instruction. The algorithms also adapt in response to new data and experiences to improve efficacy over time.

### NEURAL NETWORK

A method of machine learning based loosely on the human brain that uses "nodes" and weights information based on their importance. A neural network consists of thousands or millions of densely interconnected nodes.

### NATURAL LANGUAGE PROCESSING (NLP)

AI that can recognize, interpret, and analyze human language, whether it is spoken or written. NLP is often used when sorting and processing unstructured data, like medical charts, news articles, and reports, for quick reference or consolidation.

### STRUCTURED DATA

Data that has been organized into a particular format for storage, usually a database, so that the information can be more efficiently processed and analyzed.

### SUPERVISED LEARNING

A machine learning technique in which algorithms map an input to an output based on examples already labeled and supplied by human beings.

### UNSTRUCTURED DATA

Data that hasn't been organized into a database or other format. Unstructured data is usually text-heavy but might also include dates and numbers.

### UNSUPERVISED LEARNING

A machine learning technique in which algorithms act on unclassified, unlabeled information, usually drawing relationships between various data points to find similarities, correlations, and frequencies.

## QUADRANT 1

# Patient care

### The pain point: Trust issues

Patients don't always trust their dentists. Some have a genuine phobia, others just believe what they see in the movies and on television.

"Most of what you see are people dying or getting ripped off, or portrayals of dentists as bumbling idiots or sadists," said Dr. Kyle Stanley, co-founder of Pearl and a practicing Los Angeles dentist who lectures on the topic of stress among dental professionals.

"There's not a lot of good PR about changing someone's smile and making them feel better."

As a result, dental patients are more likely to sue. According to one study, 89 percent of dentists are afraid of being sued, and 64 percent said that fear prompts them to refer their patients more often.

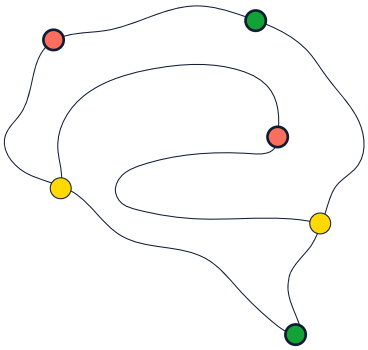
### The treatment: 20/20 computer vision

In the 21st century, people are putting their faith in technology, data, and the precision they offer. AI that incorporates computer vision can already speed up digital workflow and bring increased precision to prosthetic fabrication, ensuring that patients receive the highest quality dental restorations. It can now also examine dental imagery to identify caries and other dental pathologies faster, earlier and more accurately than a human dentist.

That "second opinion" is particularly valuable for dentists in solo practices. "It's like another dentist over your shoulder checking your work." Stanley said.

Further, it can provide validation for a dentist educating patients about their diagnosis and treatment options. With an AI-substantiated report in hand, dentists can focus less on justifying their professional opinions and more on clearly communicating their treatment plan with compassion and empathy.

A dentist backed by AI will be able to deliver better care more confidently, alleviating both the worry and financial burden of possible lawsuits. And, as more dentists adopt the software, malpractice rates will fall and, with them, the cost of liability insurance.



## QUADRANT 2

# Business operations

### The pain point: The pace of profitability

Many professionals begin their careers with student debt, but dentists carry a heavier burden than most. To start, the cost of going to dental school has increased by 400% since 1990. Dental school graduates in the United States owe nearly $300,000. Add in the costs of opening or buying a solo practice and some dentists begin their careers $1 million in debt.

While reimbursement rates have risen, they haven't kept pace with costs, Stanley said. "When my dad got out of dental school 40 years ago, insurance maximums were around $1,500. Now it's still just $2,000 at the most, even though the costs of the procedures to dentists are orders of magnitude greater."

To compensate, dentists have to work faster and see more patients in a day—about 20 every day, according to research by the American Dental Association. "Dentists have to see patients back to back, and, like everyone, when we're rushed our work suffers," Stanley said.

### The treatment: Outsource business analytics

The predictive analytics baked into data management platforms can yield business insights that help practices become more profitable. The same trends that inform patient care—diagnoses, treatment plans, related health concerns—can inform broader business decisions.

"Humans are not very good at ingesting and analyzing large, disparate data sets, but computers are excellent at it." explained AI veteran and Pearl co-founder Ophir Tanz. "With the right algorithms, you start seeing all kinds of inefficiencies and new value opportunities that were inaccessible before."

For example, when the CEO of a large network sees a large percentage of patients with bone loss, the ROI on that $50,000 dental laser is obvious. Likewise, a solo practitioner who sees a similar trend might strike a deal with a specialist who already employs that equipment.

Without math homework to do, dentists can spend more time on day-to-day operations like managing staff, marketing, and other small business concerns.

## QUADRANT 3

# Quality of life

### The pain point: Isolation and stress

Dentists love helping people look and feel great, but it can be a lonely profession. Dentists in solo practices often work alone in a windowless room with few opportunities to interact with peers. Their work is physical, hunched over patients who tense up when they approach. Not to mention the pressure of keeping the lights on.

Not surprisingly, these work stressors take their toll. There are immediate physical effects, like high blood pressure and musculoskeletal pain. There are also mental health effects. Dentists are twice as likely to suffer from depression, anxiety and panic disorders and 38 percent report being frequently or always worried.

These experiences contribute to a vicious cycle that can undermine patient confidence. Stressed, tired, and overworked dentists make mistakes, which feeds the atmosphere of fear and mistrust. “Dentists can make mistakes. We’re human,” Stanley said.

### The treatment: The human touch

No machine can provide a warm smile and a gentle touch, or reassure patients about the outcome of a proposed procedure This is the human side of dentistry that simply can’t be replicated by AI. However, with an always-on assistant, dentists have more time to focus on the patients they see every day.

With AI to help them move quickly through their day, dentists have more time to build relationships with their staff, eat a healthy lunch, get to the gym or simply get home in time to spend time with friends and family.

Professionals who spend their workday taking care of others can rely on AI to help them make time for themselves.

## QUADRANT 4

# Systemic care

### The pain point: A siloed specialty

Often, dental professionals focus only on the mouth: they examine teeth and gums and leave everything else alone. This siloing of oral health leaves too much on the table. Numerous recent studies have demonstrated an association between oral health and diseases such as Alzheimer’s, stroke, heart disease, diabetes, and autoimmune diseases.

The studies that identify these connections require untold hours of human-led effort, often spanning a decade or more. The challenge of compiling the vast quantities of data that make these studies valid isn’t going away, but it is getting smaller as our data accumulates with each new piece of research.

### The treatment: Put the mouth back in the body

AI technologies have made it possible to analyze millions of charts in order to discover associations between oral and systemic health. The knowledge that has historically required years to develop will soon require days, minutes or even seconds.

“Once we integrate the two healthcare fields, dentists won’t be just looking at the patient’s X-rays and making recommendations based on that limited information,” said Tanz. “Dentists will be able to consider patients’ holistic medical history and, with the help of AI, develop treatment plans that are informed what’s worked for patients with similar health profiles.”

What does this mean for practicing dentists? With the right software, an in-office AI could analyze a medical chart and see if a patient fits a particular pattern. For example, a woman over 50 who is missing between two and four teeth, has periodontal disease and is on blood pressure medicine is 33 percent more likely to have a stroke in the next six years. The dentist who knows that can advise her to see a physician before she continues with any dental treatments.

## PERCEPTIONS OF AI IN DENTISTRY

**63%**

Are uncertain if their dentist is reading x-rays accurately.

**55%**

Would feel more confident if another dentist verified their x-rays.

**82%**

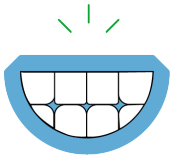
Prefer that their dentist use the most advance AI and diagnostic technology available.

*Source: Survey of nearly 1000 U.S. consumers.*

# The Future of Healthcare, Powered by AI

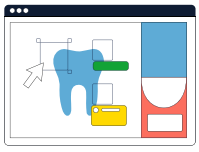
Artificial intelligence is deployed everywhere in ways that make our everyday lives and jobs run just a little smoother.

AI in dentistry is no different. By embracing the small efficiencies that AI offers—faster diagnosis, auto-charting, predictive analytics—we embark on a journey that promises so much more. And in the interim, it helps us be a little more accurate, a little more profitable, and little more trusted by our patients.



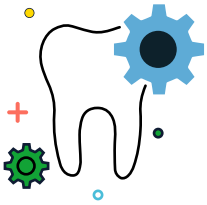
## Smart smiles

Using facial recognition technology and 3D computer imaging, dentists will be better able to engineer smiles to fit a patient's unique bone structure.



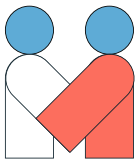
## Mobile practices

Dental vans are often deployed in areas where resources are scarce. But enterprising practices will be able to deploy a single clinician and mobile x-ray machine in office parks and other high traffic areas to take scans, run them through the software, and make follow up appointments with patients who need them.



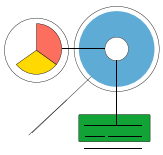
## Haptic education

Dental students at the University of Pennsylvania use gloves enabled with haptic sensors that simulate touch to simulate performing procedures like pulling teeth or performing surgery. As haptic technologies advance, expect to see them deployed for continuing education. Practicing dentists will use them with remote video and e-learning to learn and perfect new procedures.



## Talent development

AI can be used to evaluate potential hires, vetting them against not only the AI but against their more established peers. This capability will be particularly helpful for large networks that sift through applications from dozens of new grads.



## Spotting public health trends

Artificial intelligence allows researchers to crunch large data sets to find correlations between symptoms that indicate the need for further study, trends within subpopulations, and more. When thousands of private practices engage with applications that feed large data sets, predictive analytics can draw relationships between data sets it could take researchers years to uncover.

## Better care in underserved areas

When deployed at general health clinics, AI-driven dental care software can scan x-rays, label abnormalities and tell patients if they need to find a dentist or specialist. This saves time and expense for patients who might live an hour's drive or more from the nearest dentist.

# Hello, Pearl

**Our technology solutions put dentists and patients at ease.**

Our products were built with the dentist in mind and the patient at heart. Using the latest innovations in artificial intelligence and over 10 years of expertise in computer vision, Pearl is ushering in a new wave of AI-powered dentistry tools: Second Opinion to build trust with patients and reduce liability, Practice Intelligence to make practices more efficient and streamlined and Smart Margin to automate a more precise and cost-effective dental restoration process.

## SECOND OPINION

In the world of dentistry, flawed or inconsistent x-ray readings are all too common. That's bad for patient trust—and can even put a dentist's practice at risk. That's why we developed Second Opinion—a computer vision platform that can instantly and reliably identify dozens of common pathologies. Trained on x-rays annotated by a team of world-renowned dentists, our system gives dentists and patients the peace of mind they deserve. And it learns from dentists' live feedback, so the system is always getting better––making Second Opinion the only one you'll ever need.

## PRACTICE INTELLIGENCE

Managing dental practices with hundreds—even thousands—of patients can be impossible without highly specialized data from which staff can make sound decisions. How many patients do you have with 1-2mm of bone loss? Are your new graduate doctors diagnosing accurate treatments compared to your most seasoned and experienced dentists? Do you have enough patients consulting on their wisdom teeth to bring a specialist in more than once per week? Decisions based on this data can influence everything from hiring and firing to marketing, training, and ROI. Practice Intelligence uses computer vision software to drill down to the office-specific data that matters—even while you're on-the-go.

## SMART MARGIN

Creating a perfect dental restoration is a complex process. It requires that technicians examine digital models and manually mark where tooth and restoration meet. Margin marking is a time-consuming, error-prone exercise. Mistakes result in unusable restorations—and wasted time and money for all concerned. But help is here. Our AI-powered technology is revolutionizing the dental restoration process. Smart Margin has been trained by dental professionals to instantly score scans and execute margin marking with super-human accuracy, saving serious time and expense for dental labs and their clients.

## SCAN CLARITY SCORE & SMART

Dental laboratories are often frustrated with the quality of scans sent to them for restoration fabrication. Issues range from lack of a visible margin, missing contact points, or defects in the scan. Pearl's Scan Clarity Score allows dental labs to score and bucket each patient scan based on margin clarity. If the scan is of high enough quality, the margin is automatically marked and sent on for crown design. If the margin clarity score is low, it is flagged for human intervention and/or for a call to be placed to the dentist. By systematically processing the quality of margins, dental labs, dentists, and, most importantly, patients benefit with higher quality dental restorations.