OPEN WIDE

How AI is reshaping the future of dentistry

PATIENT
Eileen Hathaway

AGE
62

GENDER
F

COMPLAINT
Tooth pain on the lower right side.

HISTORY
Receding gums in the lower right quadrant, 2-3 mm bone loss around 27, 28, over 12 months. Tooth loss, 29, six months ago.

MEDICATIONS
Thyroid medication, ibuprofen for ongoing back pain.

DIAGNOSIS
Periapical infection; high risk of diabetes.

TREATMENT PLAN
Extraction with implant placement following appt. with general practitioner for blood sugar screening.

I t's 8:45 a.m. on a Monday and—thanks to a pile-up on the 405—you're late for your first appointment. No matter. You already know the score: Your patient has a periapical infection, suffers from thyroid problems, and should probably get checked for diabetes. No, you're not clairvoyant. You're backed by **artificial intelligence.**

Artificial intelligence, long ballyhood by futurists and science fiction writers, is poised to reshape dentistry. 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—computer vision, predictive analytics, haptic engineering, telemedicine—are just a few clicks away from changing the way you work. How? We'll tell you. Just sit back, relax, and open (your mind) wide. This won't hurt a bit.

Let's poke around a little

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. Baby Boomers will likely keep more of their teeth than their parents, increasing the demand for complicated work like bridges, the BLS said. And Millennials, now firmly in their late 30s, have children of their own to make appointments for. In all, it's a good time to be a dentist.

Still, there are tender spots. To start, people don't always trust their dentists. Some patients have a genuine phobia, but poor media portrayals have prejudiced others, said Dr. Kyle Stanley, a Los Angeles dentist, vice president of Pearl and global lecturer on the topic of stress among dental professionals.

"Most of what you see are people getting ripped off, or portrayals of dentists as bumbling idiots or sadists," Stanley said. "There's not a lot of good PR about changing someone's smile and making them feel better."

This mistrust puts dentists in the unenviable position of having to win their patients' trust. It also contributes to a chronic fear of being sued, Stanley said. "If we miss something, if we overdiagnose, everyone

wants to sue dentists." According to a study by Dental Protection, a trade organization based in the United Kingdom, 89 percent of dentists are afraid of being sued, and 64 percent said that threat has resulted in them making more referrals.

Dentists can't afford to lose that business. While reimbursement rates have risen in the past several years, they haven't kept pace with costs, Stanley said. "When my dad got out of dental school, reimbursement was $1,500. Now it's $2,000 at the most. But replacing a crown costs between $1,500-$3,500. So it's orders of magnitude more expensive, but the insurance hasn't increased." To compensate, dentists depend on patient volume. In 2017, dentists saw an average of 2.5 patients an hour, or about 20 per day, according to research by the American Dental Association.

"Dentists have to see patients back to back, and they can't really do a good job," Stanley said. Tired, overworked dentists make mistakes, which feeds mistrust among patients and fear of being sued among dentists. "Dentists can make mistakes. We're human."

I, Dentist: AI upgrades for every quadrant

1 **2**

3 **4**

Dentists supported by AI have the opportunity to make significant steps forward. The AI software available to dentists today helps them work faster, smarter and more accurately than ever before. And, when working in concert with other technologies, AI will open opportunities beyond the four walls of a dental practice.

Most artificial intelligence deploys some combination of computer vision (the processing and understanding of digital imagery), machine learning (data-driven algorithms that enable computers to learn underlying patterns about the data they process), and predictive analytics (statistical modeling used to find or forecast patterns and outcomes). Medicine is already applying AI in hospitals, where doctors use those technologies in software that identifies abnormalities in brain, heart and lung scans. And the technology does so with speed and precision. In 2011, researchers from NYU Langone Health found that computer vision could find and match specific lung nodules on chest scans between 62 to 97 percent faster than a panel of radiologists.

Dentists can do the same using Pearl, a computer vision platform that scans and annotates X-rays to identify pathologies like tooth decay and bone loss, as well as past dental work and natural anatomy. Pearl, an established computer vision company with longstanding business lines in advertising and sports, built the dental care application with the help of Dr. Stanley and the cooperation of the University of Pennsylvania Dental school.

Pearl trained its AI platform on millions of images annotated by global leading experts in dentistry and uses computer vision and machine learning to identify dozens of pathologies with greater accuracy. The system's next generation will be able to use natural language processing and predictive analytics to scan patient histories and medical records to find trends, predict progressions and chart treatment plans. Taken together, this kind of software can have a dramatic impact on the day-to-day operations of a dental office.

Patient care

People don't always trust their dentists, but they do trust computers. In the 21st century, humanity has put its faith in technology, data, and the precision they offer. To some extent, they're right. AI can identify caries and other dental pathologies faster, earlier and more accurately than a human dentist.
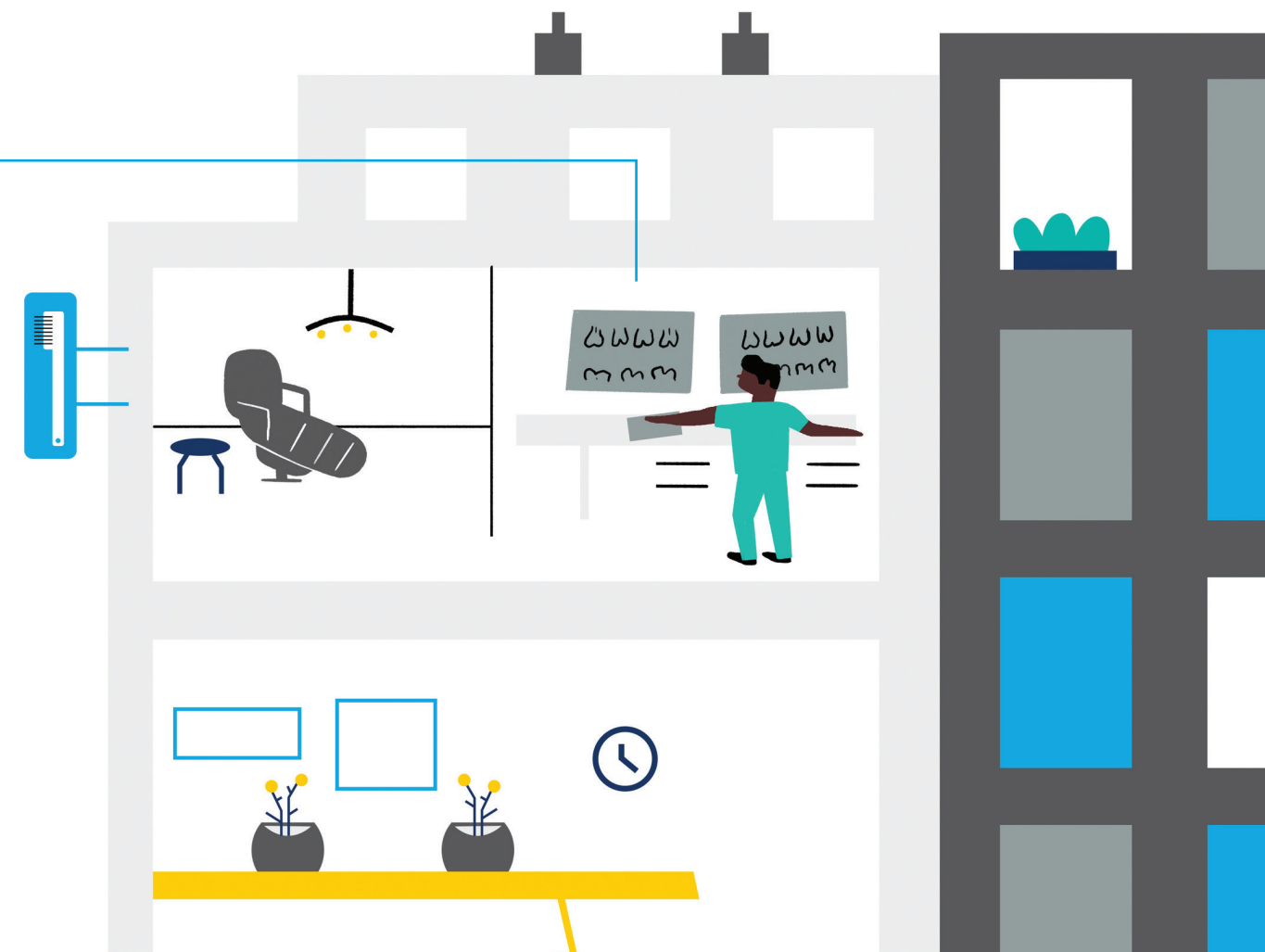
That "second opinion" is particularly valuable for dentists in solo practices. "It's like another dentist over your shoulder checking your work and saying, 'Hey, did you see this cavity back here' or 'did you see that there's this infection here,' because we miss it sometimes," Stanley said.

Further, it can provide backup when a dentist is educating patients about their diagnosis and treatment options. "Patients have to know that dentists are doing what's best for them," Ada S. Cooper, a consumer adviser for the American Dental Association told U.S. News and World Report. With an AI-backed report in hand, dentists can focus less on justifying their professional opinions and more on clearly communicating their treatment plan with compassion and empathy.

What's more, Pearl analyzes unstructured data within a patient's medical record and ties it back to more massive datasets, then uses predictive analytics to surface other health concerns. While dental-only practices are still the norm, dentists are joining integrated practices and networks with increasing frequency. This new place in holistic practices gives dentists the chance to play a more significant role in patient health and the larger healthcare community by working with other care providers to improve a community's overall health.

WHAT'S NEXT

Computer vision will be able to accurately calculate and mark the margins needed to create crowns, veneers and other dental restorations in milliseconds. This new technology will reduce cost, errors and help dentists create better fitting treatments.

Talent development

Dental colleges like Penn Dental Medicine and Columbia School of Dentistry are at the forefront of advanced technologies, using methods like electronic learning, gamification and more to deliver a new generation of tech-savvy docs.

At the University of Pennsylvania, students use gloves enabled with haptic sensors that get the feel of touch to simulate performing procedures like pulling teeth or performing surgery, said Dr. Markus Blatz, DDS, and Director of Innovation at Penn. Likewise, gamification schemes aid learning and hybrid lesson plans that incorporate video and e-learning with traditional classroom studies are helping train new dentists.

Big data and predictive analytics are also playing a larger role at Columbia, where their Center for Precision Care uses "smart chairs" that collect data like heart rate and blood oxygen levels to monitor stress levels in real time. Instruments are also tagged, and students and patients wear RFID tags to monitor technique and other feedback that informs instruction and patient research.

"Using machine learning algorithms we can determine what is causing those stresses and how can we reduce the causes of

those stresses," said Jeanette Wing, Avanessians Director at Columbia University's Data Science Institute.

Once dental students enter the job market, artificial intelligence can be used to evaluate potential hires, vetting them against the AI and their more established peers. This capability will be particularly helpful for large networks that more often hire new grads, said Stanley. "They can say, 'Is my new grad diagnosing and treatment planning just as accurately as my doctor that's been with me for 20 years?'"

WHAT'S NEXT

As haptic technologies advance, expect to see them deployed for continuing education. Practicing dentists can use them in combination with remote video and electronic learning to learn and perfect new procedures.

Business operations

When a dentist sees 20 patients a day, speed is of the essence. AI that quickly identifies pathologies not only allows for more interaction with patients, but also enables dentists to focus on day-to-day operations like planning, managing staff and evaluating new equipment.

Predictive analytics within any data management platform can also yield business insights. The same trends that inform patient care— diagnoses, treatment plans, related health concerns—can inform other decisions. And the larger the practice or network, the more data there is to work with, the better the insights will be. When the CEO of a large network sees a large percentage of patients with bone loss, they may consider buying that $50,000 dental laser. Likewise, a solo practitioner who sees a similar trend might strike a deal with a specialist who already employs that equipment.

WHAT'S NEXT

Mobile 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.

Public health

The Centers for Disease Control undertakes a National Health and Nutrition Survey that includes oral health every year, but the population sample is limited and the question set addresses only baseline concerns. However, when thousands of private practices engage with applications that feed large data sets, the benefits to public health can be substantial.

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. Every time a dentist inputs their X-rays and patient files into Pearl, the application's ability to find abnormalities and link them to other health concerns improves.

"If we have millions of patients that have 1-2mm of bone loss, are missing three or more teeth, and have heart disease, we can start making predictive statistics through large data sets." said Stanley. "We can make those predictions once we have the data."

WHAT'S NEXT

Dental AI platforms like Pearl's can improve access to care in underserved areas. When deployed at health clinics, the software will let patients know if they need to seek out a general dentistry or specialist appointment without traveling a great distance.
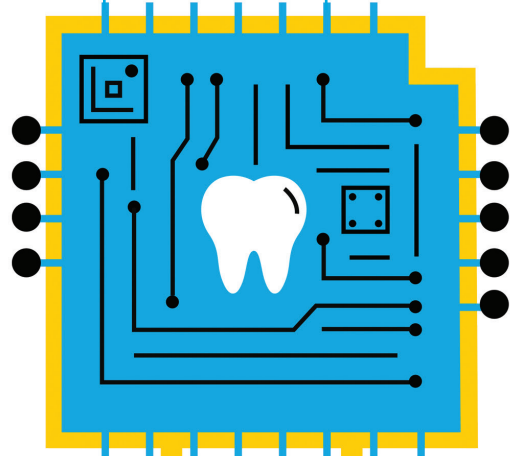
Keep calm and carie on

Artificial intelligence, deployed on a large scale, promises a great many things. Economic growth, efficiency, life-changing technologies and more. But every day it is deployed in ways that make our lives and jobs run just a little smoother.

AI in dentistry is poised to revolutionize your day-to-day practice. By embracing the incremental efficiencies that AI offers—faster diagnosis, auto-charting, predictive analytics—we start together down a long road that promises so much more. Holistic health care, improved access to dentistry, and better quality of life for dentists themselves, are all in our future, thanks to AI. Dentists who incorporate these new technologies will find they are more accurate, profitable, and more trusted by patients. That's a future we don't have to wait for any longer.
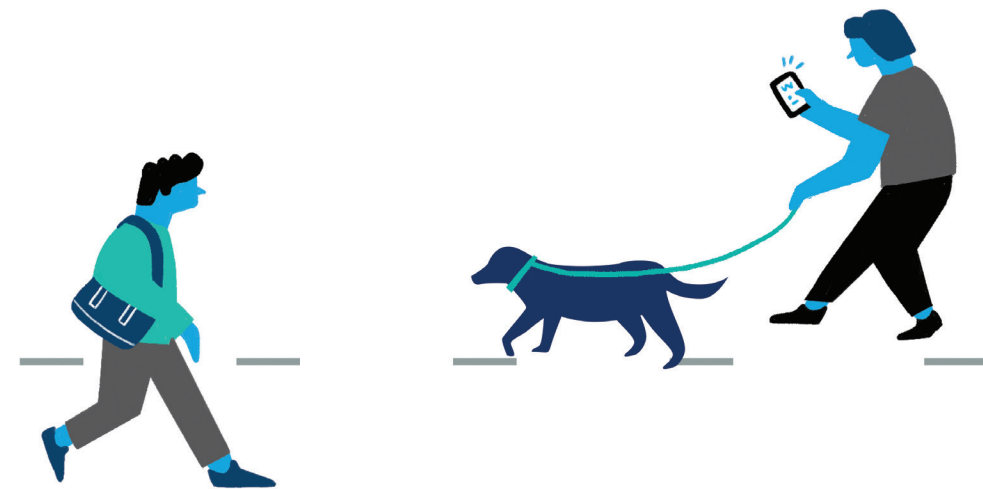
Drilling down: What is AI and how does it work?

AI has always gotten a bad rap in pop culture. About as bad a rap as dentists. It's been sent from the future. It won't open the pod bay doors. It's here to optimize us (or at least our jobs) out of existence. In reality, AI is much more quotidien.

Artificial intelligence—the application of algorithms, statistics and other kinds of computing power—is being used in every corner to automate mundane tasks. Taking notes, making appointments, sorting and labelling images are all tasks that, until recently, required human attention. Not anymore. Now, software purporting to integrate artificial intelligence is promising to liberate people from all manner of busywork.

Why? While artificial intelligence as a concept has been around since 1956, recent advances in computing power and storage along with the proliferation of big data has propelled AI from hype to reality. In other words, cheaper, faster, computer chips can now be clustered together to support the software AI needs to process all the data we're churning out online.

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. Or, you know, when the machines rise. Either way, you'll want to know the lingo.

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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. Pearl's platform was trained on millions of images marked up by dental experts. Each time the computer correctly scans and sorts a new image, the artificial intelligence improves, much in the way a human being learns through trial and error.

SUPERVISED LEARNING

A method of machine learning in which artificial intelligence is trained on data that has already been classified or categorized, then learns to identify patterns or outcomes based on those examples. Pearl's platform uses supervised learning, because its AI has been trained on millions of X-rays already annotated by human experts.

UNSUPERVISED LEARNING

A method of machine learning in which artificial intelligence is given data that has not been classified or categorized. The algorithms then work to identify commonalities in the data, for example relationships between oral health conditions and other data points, like other health indicators or demographic information.

COMPUTER VISION

AI that can analyze visual data and then make decisions about it. Pearl's platform uses computer vision to recognize abnormalities in X-rays, helping dentists quickly diagnose pathologies like cracked teeth, tooth decay and other caries.

NATURAL LANGUAGE PROCESSING

AI that can recognize, interpret, and analyze human language, whether it is spoken or written. NLP is often used when 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. Data on patients in a practice that have been seen in the last six months, for example, may be organized into an Excel sheet. That structured data can be analyzed to predict trends like patient volume, typical diagnoses and supplies needed.

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. Medical charts, dentist's notes, and emails all comprise unstructured data.

Welcome to Smile City, population 75,600. Here, the water is fluorinated, the paperwork is automated and the dentists are connected and optimized. That's because they're using a network of advanced technologies to keep the citizens carie-free.

COMPUTER VISION
Smile City's root system. Underpinned by AI that analyzes visual data, dentists here can diagnose up to a dozen pathologies earlier and more accurately than they could before. And, every time a dentist uploads their own patients' images, the system learns from that data and becomes even smarter.

MOBILE DENTISTRY
When equipped with AI, mobile dentists can see more patients in resource-starved areas, analyzing images, making treatment plans and providing referrals within minutes.

INTEGRATED CARE
Dental offices are already being incorporated into full-service practices. When AI detects a problem that could link to a patient's broader health, the dentist can simply refer them to a partner for help.

SMART MARGIN
Getting the right fit for a dental restoration is crucial, but mistakes happen. Restorations fashioned from inaccurate markings are unusable and waste time and money. AI marks those measurements with superhuman accuracy, ensuring dental labs get it right the first time.

SECOND OPINION
In the demanding world of dentistry, one set of eyes just isn't enough. Here, dentists rely on AI to ensure they're reading X-rays accurately, even at the end of a long day. A second opinion, trained on millions of expertly annotated images, gives dentists and their patients peace of mind.

VIRTUAL CONSULTATIONS
People who don't live near their dentist sometimes skimp on their oral health. Imagine a world where a patient can virtually upload an image of their teeth for AI analysis, then talk to a dentist who interprets the results and communicates a treatment plan.

AUTO-CHARTING
In Smile City, dentists don't need to thumb through paper patient records. AI counts teeth, compiles diagnosis, and creates a downloadable report for dentists to consider at the press of a button.

PREDICTIVE ANALYSIS
AI analyzes data in patients' medical and dental records, allowing it to recognize trends across patients and across time. Poor oral health has been linked to heart disease, Alzheimer's Disease, and diabetes, so finding patterns early could save lives.

The Future of Healthcare, Powered By AI

Perceptions of AI in dentistry

63%

Are uncertain if their dentist is reading X-rays accurately.
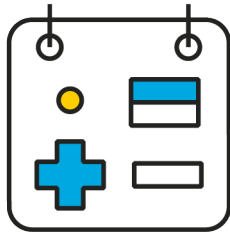
55%

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

82%

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

SURVEY OF NEARLY 100 U.S. CONSUMERS

How AI benefits the dentist

SUPERIOR PATIENT CARE

Our unbiased AI system was trained by dentists from around the world to give patients more information on their diagnoses.

LIGHTNING-FAST DATA ENTRY

Our system handles auto charting and creates medical and legal records in a matter of moments. We can even automatically annotate evidence for billing.

OPTIMIZE PRACTICE PERFORMANCE

Dental practices can generate on-demand performance reports that detail where associate doctors are missing things, and identify opportunities in the patient pool.

Our Products

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, existing restorations, and natural anatomy. 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.
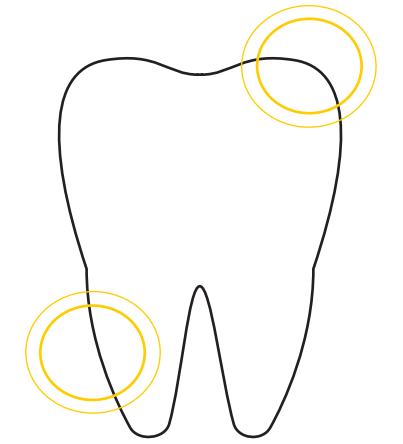
Smart Margin

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 execute margin marking with super-human accuracy, saving serious time, and expense for dental labs and their clients.
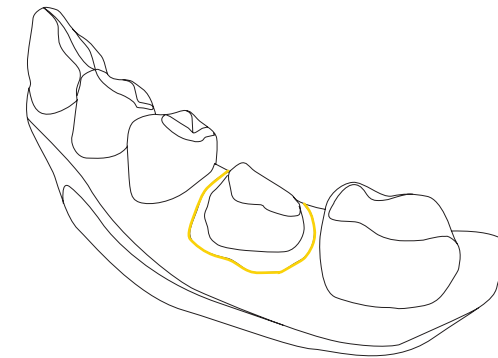
Practice Intelligence

Managing a dental practice with hundreds—even thousands—of patients can be impossible without highly specialized data that your staff can make sound decisions from. 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 quickly drill down to the office-specific data that matters most—even while you're on-the-go.

ABOUT PEARL

Peral is a suite of AI solutions that assists dentists
in identifying issues earlier and with higher precision. Using
proprietary X-ray analysis capabilities, Pearl will recognize dozens
of dental pathologies, existing restorations and natural anatomy,
allowing practitioners to assess robust data across their practice,
spend more time with patients and prescribe better treatment
options.

www.hellopearl.com