

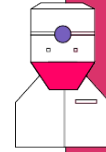
# Inconsistency in Radiographic Dental Diagnostics & Treatment Planning

A study of variability in the diagnoses and treatment plans – with estimated costs – proposed by 136 dentists based on evaluation of a single full-mouth X-ray series.



## Abstract

A full mouth dental radiographic series was presented to 136 licensed dentists, both in the United States and abroad, together with lists of 11 diagnoses and 29 potential treatments. Respondents were asked to identify pathologies they detected and to select treatments they deemed appropriate. Representative prices were then assigned to each treatment and the total cost of the treatment plan to the patient calculated.



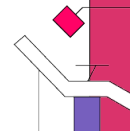
**136**  
dentists



**1**  
FMX



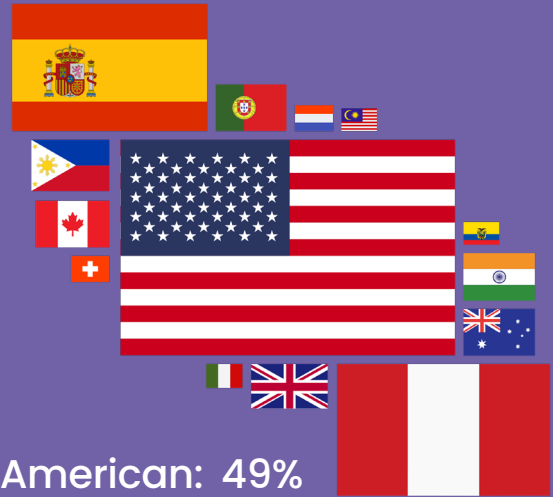
**11**  
diagnoses



**29**  
treatments

## Profile of Respondents

Of the 136 participants in the study, 66, or approximately half, practice in the United States. All major regions of the US are represented. Foreign respondents practice in the UK (3), Switzerland (1), Spain (21), Portugal (2), Philippines (3), Peru (27), Netherlands (1), Malaysia (1), Italy (1), India (4), Ecuador (1), Canada (2) and Australia (3). Years in practice range from 2 to 44. Male respondents number 71, female 65. In general, respondents obtained their training in the country in which they practice, with the notable exception that 40 percent of the respondents practicing in Spain trained in Venezuela.

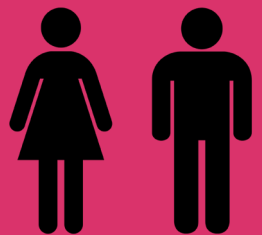


American: 49%  
 Peruvian: 20%  
 Spanish: 15%  
 Indian: 3%  
 British: 2%  
 Philippino: 2%  
 Austrailian: 2%  
 Other: 7%



## 14.6 Years

Avg. Practice Experience



48% 52%

## Assignment of costs

In order to compare the costs of proposed treatment plans, a representative price, typical of current practice in the United States, was assigned to each procedure by an experienced practitioner. The same cost factors were applied in all instances, without regard to regional, demographic or national differences. No attempt was made to judge whether some diagnoses or treatments were more correct or appropriate than others.

TREATMENT	COST
Filling: Amalgam - 1 to 4+ surface	\$100-\$250
Filling: Resin - 1 to 4+ surface	\$150-\$300
Inlay/onlay: metallic - 1 to 3+ surface	\$800
Inlay/onlay: porc/ceramic - 1 to 3+ surface	\$1000
Crown: metal/ceramic/porc. fused to metal	\$1000-\$1200
Root Canal	\$1000
Build up	\$250
Post and core	\$250
Clinical crown lengthening	\$600
Bridge	\$3000
Extraction	\$200
Bone Graft	\$400
Implant Placement	\$2000
Prefabricated abutment	\$800
Custom fabricated abutment	\$1000
Abut. supported crown	\$1500

Table 1. Estimated cost in U.S. dollars of treatment options featured in the study.

## Quality of Data

Granular examination of the data set reveals a certain number of inconsistencies, contradictions, duplications or omissions. For example, when asked to choose from among three levels of depth of penetration of

caries -- into enamel, into dentin, to pulp -- most respondents selected only the deepest penetration they perceived. A few, however, selected the deepest as well as all less severe options, since penetration to the pulp naturally implied penetration into enamel and dentin as well. As a result, there could be more diagnoses of penetration depth for a single tooth than there were respondents to the survey.

Some anomalies are clearly due to differences in interpretation of the task, while some others may be due to carelessness, oversight, or accident. Filling out a survey is not the same as treating a live patient, and the pressure to be absolutely accurate is not so great. Nevertheless, respondents were not anonymous, and so professional pride as well as competitive instinct motivated respondents to be careful and accurate in their judgments. The number of errors is small compared with the number of responses, and does not materially affect the conclusions.

## Background

Clinicians, patients and insurers are aware of widespread inconsistency in dental diagnosis and treatment. For a 1997 Reader's Digest story, an investigative journalist visited 50 different dentists around the country and received a different diagnosis and treatment plan from nearly every one. That account has been validated in other studies, including one recently produced by the company Pearl, which asked three dentists to identify caries in a set of 8,767 dental radiographs. In 79 percent

of cases all three concurred that no decay was present. When decay was identified by at least one of them, however, one or both of the other two disagreed 80 percent of the time. Since the identification and treatment of caries consumes a large portion of the efforts of many dental practices, the lack of unanimity was striking.

The present study enrolls a much larger number and variety of respondents and examines a wider range of pathologies. All respondents were presented with the same set of whole-mouth radiographs. The mouth in question provided fertile terrain for a diagnostic and treatment planning assessment; not a single tooth was judged fully sound, and not a single one of the available diagnoses, ranging from caries of various degrees of severity to periapical radiolucency, impaction and bone loss, failed to be detected somewhere by at least one respondent.

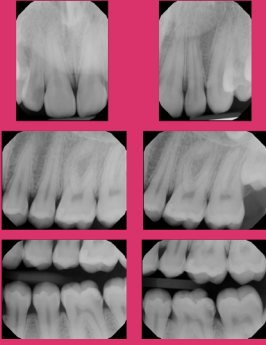
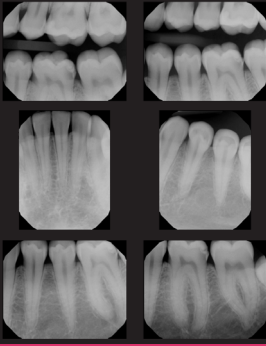
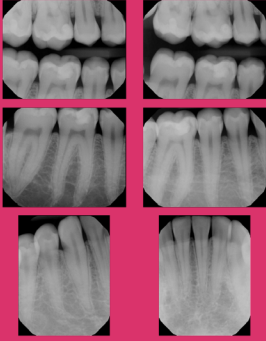
Radiographs	Tooth #	Avg. # of Diag.
	1	0.22
	2	1.14
	3	2.14
	4	1.03
	5	1.13
	6	0.49
	7	0.69
	8	0.12
	9	0.15
	10	0.29
	11	0.22
	12	0.51
	13	0.77
	14	1.58
	15	0.21
	16	0.68
	17	0.65
	18	0.35
	19	2.29
	20	0.89
	21	0.60
	22	0.13
	23	0.03
	24	0.05
	25	0.11
	26	0.09
	27	0.43
	28	0.48
	29	1.37
	30	2.43
	31	1.12
	32	0.29

Table 2. Full-mouth radiograph series (FMX) featured in the study and average number of diagnoses ascribed to each tooth by each respondent.

## Inconsistencies in diagnosis and treatment

Lack of diagnostic consistency is again clearly apparent in this study. In no case, for example, did respondents unanimously agree upon the existence of decay in a tooth, even when a large majority did. Opinions also differed, when caries were identified, as to whether penetration was through enamel, dentin, or to the pulp, and whether or not the decay was recurrent.

	Into enamel	Into dentin	Into pulp
Tooth 3	18%	71%	11%
Tooth 4	91%	9%	0%
Tooth 5	70%	26%	4%
Tooth 7	11%	18%	71%
Tooth 13	58%	42%	0%
Tooth 19	17%	38%	45%
Tooth 20	86%	14%	0%
Tooth 29	44%	56%	1%
Tooth 30	28%	63%	9%
Tooth 31	74%	26%	0%

Table 2. Percent breakdown by lesion depth for caries detected in the 10 teeth for which caries diagnosis was indicated by the greatest number of respondents.

In many teeth, only a small number of respondents identified decay; either the majority overlooked it, or it was not really there.

Other conditions, such as bone loss, were detected by smaller numbers of respondents, and those who identified bone loss commonly did not agree about its location.

In no instance did more than 81 percent of respondents concur in a diagnosis.

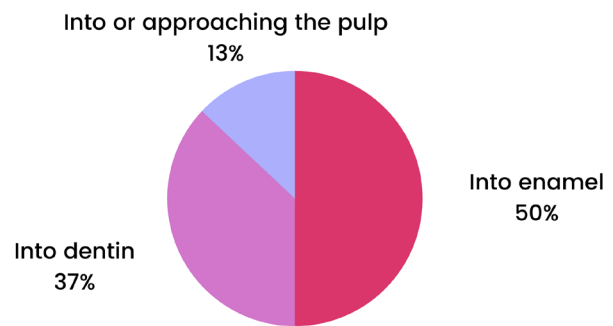


Figure 1. Average percent lesion depth breakdown for all teeth in which caries was diagnosed.

Highest levels of agreement occurred in identifying the presence of non-metallic fillings (81%), impacted molars (65%) and recurrent decay (63%). By and large, levels of diagnostic concurrence were below 50 percent, although they were higher when related categories were combined (e.g. caries with various depths of penetration).

Survey results for Tooth 3 and Tooth 19 were selected for more detailed analysis.

More than 80 percent of respondents identified the presence of an existing non-metallic restoration in Tooth 3. Sixty percent diagnosed recurrent decay. Three percent identified bone loss, and a few advanced other diagnoses.

Significantly, while 45 percent of respondents identified decay sufficiently severe to penetrate into dentin or to approach or enter the pulp, 44 percent failed to identify decay in Tooth 3 at all.

Nineteen percent of respondents who diagnosed pathology in Tooth 3 considered no treatment necessary. Among respondents who identified treatments, 45 percent chose filling,

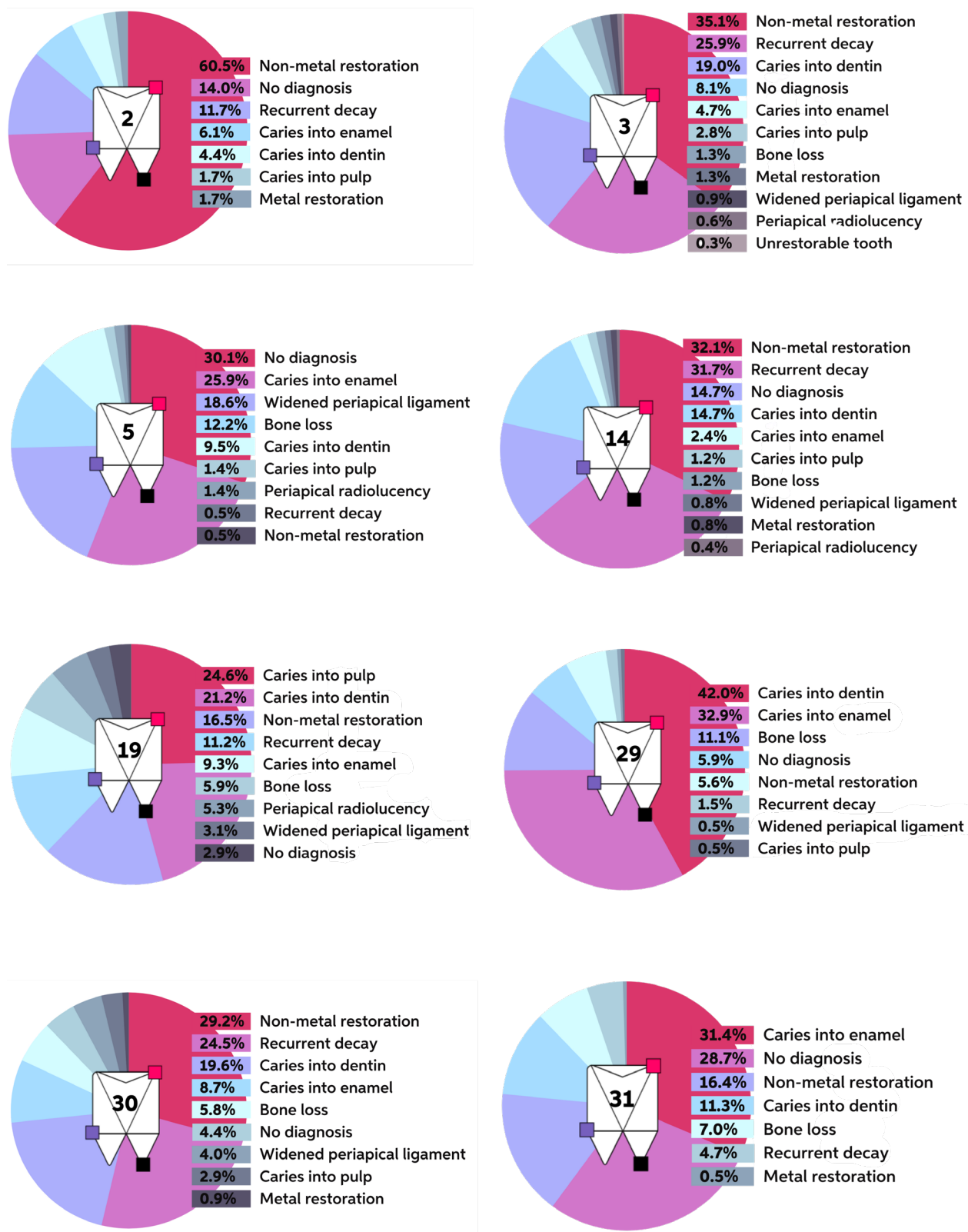


Figure 2. Diagnostic concurrence relative to total number of diagnoses for the 8 teeth with the most total diagnoses.

either amalgam or, more often, resin-based, of one or more surfaces; 17 percent a crown; and 18 percent a porcelain/ceramic or metal inlay/onlay.

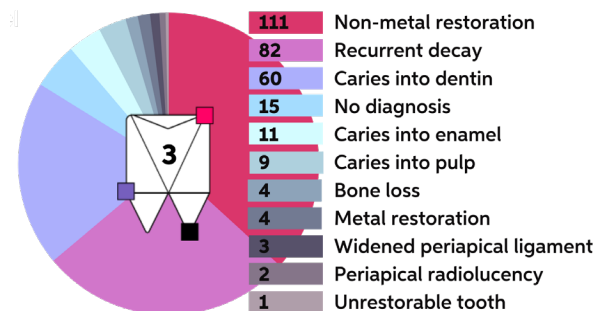


Figure 3. Total incidence for diagnoses indicated for Tooth 3.

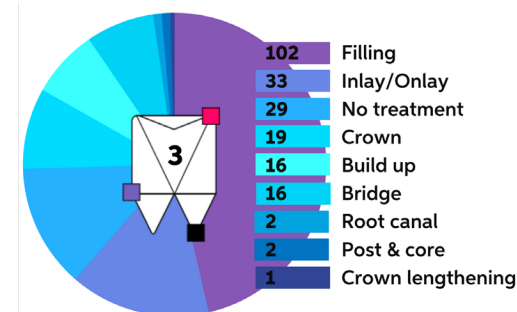


Figure 4. Total incidence of each treatment indicated for Tooth 3, ignoring variation in materials and scope of application (e.g. "Filling" total reflects resin-composite and amalgam fillings applied to 1, 2, 3, and 4 or more surfaces.)

Because of the prevalence of fillings among the proposed treatments, costs tended to be on the low side, but in a significant number of cases entailing more elaborate interventions they exceeded the average by a factor of as much as five.

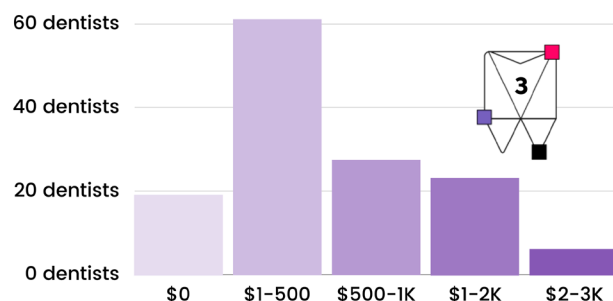


Figure 5. Variability in estimated costs of treatments indicated for Tooth 3 by study respondents, reflected as the number of dentists whose indicated treatments fell within a specified cost range.

More severe decay was identified in Tooth 19, with 58 percent of respondents assessing penetration approaching or progressing into the pulp. Other pathologies were identified by 34 percent of respondents, including periapical radiolucency (13%), widened periapical ligament (7%), and bone loss (14%)

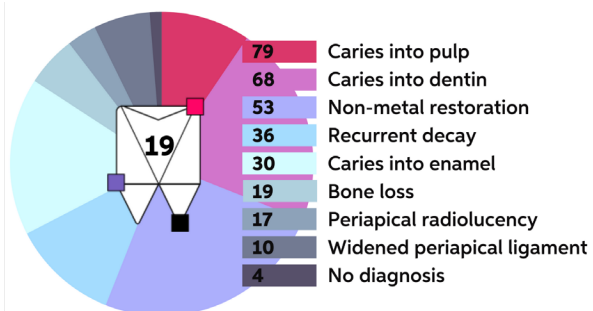


Figure 6. Total incidence of diagnoses indicated for Tooth 19.

In this case the range of treatment options was wider. Fewer than 9 percent of respondents proposed forgoing treatment. Among those who proposed treatments, 34 percent recommended at least a crown, with more than half of those adding root canal and in many cases crown lengthening; 28 percent recommended inlay or onlay; 22 percent filling; and the remaining 7 percent divided between bridge and implant.

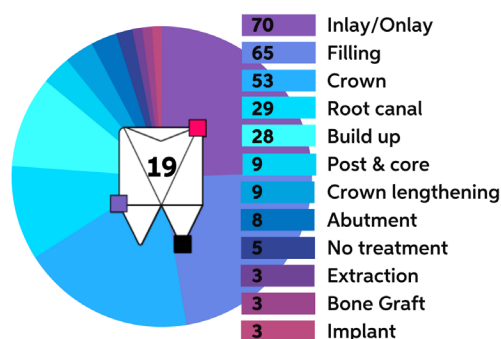


Figure 7. Total incidence of each treatment indicated for Tooth 19, ignoring variation in materials and scope of application (e.g. "Filling" total reflects resin-composite and amalgam fillings applied to 1, 2, 3, and 4 or more surfaces.)



Clearly, the range of possible costs in this case was much larger than Tooth 3, and the average cost estimate was substantially higher, driven upward by small numbers of more costly procedures. The highest estimates for Tooth 19 were around ten times the lowest (omitting respondents who chose not to treat).

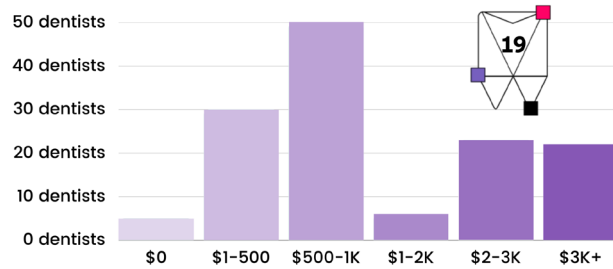


Figure 5. Variability in estimated costs of treatments indicated for Tooth 19 by study respondents, reflected as the number of dentists whose indicated treatments fell within a specified cost range.

## Aggregated cost

Using the fictional, but representative, costs assigned to different procedures for the purposes of this study, one arrives at whole mouth treatment costs as low as a few hundred dollars or as high as \$36,000. While this last figure was an extreme outlier, five respondents ran up costs greater than \$18,000. If these, along with the no-treatment/no-cost responses, are omitted from consideration, the highest cost of proposed treatment is still 20 or more times greater than the lowest.

## National differences

Tooth 16 was identified by 89 respondents as impacted, but only one respondent outside the US proposed extracting it, while 51 of 66 US respondents did. Tooth 1 was identified by 26 as impacted; of these 24 were in the US. Only US

dentists recommended extraction of Tooth 1; two supplemented extraction with bone grafts for both Tooth 1 and Tooth 16. It appears that the routine extraction of impacted third molars may be a peculiarity of US dentistry.

Periapical radiolucency was diagnosed by US dentists four times as frequently as by non-US ones.

No non-US dentist judged any tooth to be “unrestorable;” five US dentists did.

## Conclusion

Omitting regional and market differences, variability in dental treatment costs arises from two fundamental causes. One is the choice of treatment for a given diagnosis. As is apparent from the two examples analyzed above, the variety of possible treatments and the range of their possible cost increase with the severity of the identified pathology. The extent of decay in Tooth 19 was generally perceived to be greater than in Tooth 3 and to justify more complex and costly interventions, with the result that the ratio of the highest to the lowest cost estimates for Tooth 19 is 10 to one, twice that for Tooth 3.

The second driver of variability is uncertainty in diagnosis. Both this study and the previous Pearl study reveal a striking lack of consistency in identifying the presence or absence of pathology, as well as its severity. A diagnosis of more severe disease opens the door to a wider variety of increasingly costly treatments. An example can be seen in Tooth 19, where the most widely chosen treatments, filling and

inlay/onlay, cost hundreds of dollars, while others, such as crown, root canal and crown lengthening, which were considered advisable by almost as many respondents, may cost thousands.

While it is to be expected that different dentists may select different treatments for a given condition based on experience or personal preference, inconsistencies in diagnostic performance appear likely to multiply the effects of those differences, causing one patient or insurer to pay many times what another pays for the same outcome. It is difficult to quantify the multiplier effect in a general way, but it is clear from this study that costs to patients and insurers may be exponentially sensitive to seemingly minor differences in diagnosis.

# About the DAIC

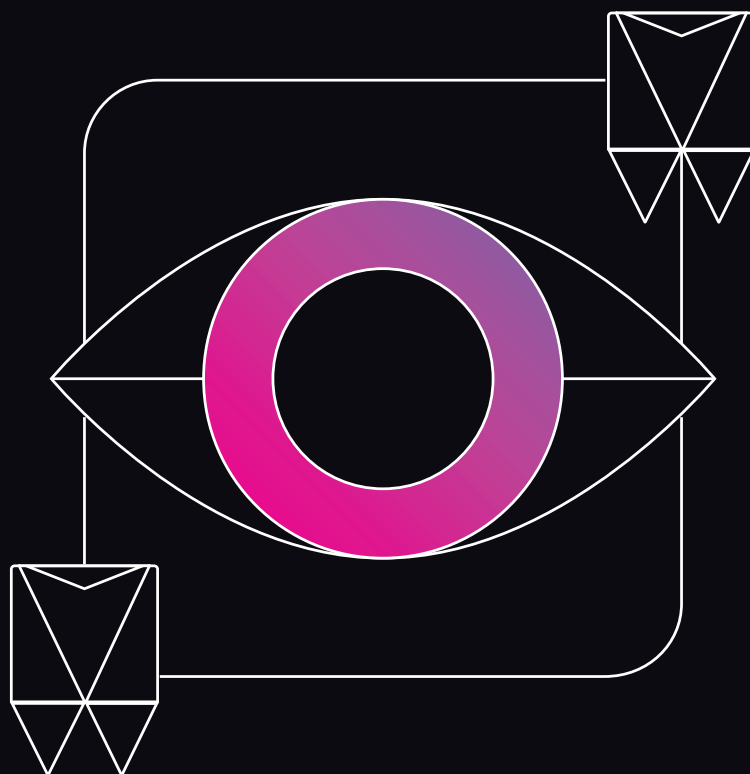
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The Dental AI Council (DAIC) is a non-profit organization devoted to helping define the future of artificial intelligence (AI) in dentistry. It brings together leaders from across the dental category to advance research, education, and thought leadership on AI and its dental applications. Organized by the AI company Pearl, the DAIC's members represent every dental industry constituency, including practitioners, dental service organizations, equipment manufacturers, practice management software providers, insurance carriers, laboratories and universities.

## Mission

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AI is poised to enact profound change across the field of dentistry. We will see dramatic increases in accuracy and transparency, improved patient care and automation on a variety of levels. This is a truly exciting time and has given rise to many questions. The DAIC's mission is to advance research, education and thought leadership that helps answer those questions, while bringing clarity and foresight to the discourse surrounding AI's role in the dental industry of tomorrow.



**DAIC** DENTAL AI  
COUNCIL