O-pH: Optical pH Monitor to Measure Dental Biofilm Acidity and Assist in Enamel Health Monitoring

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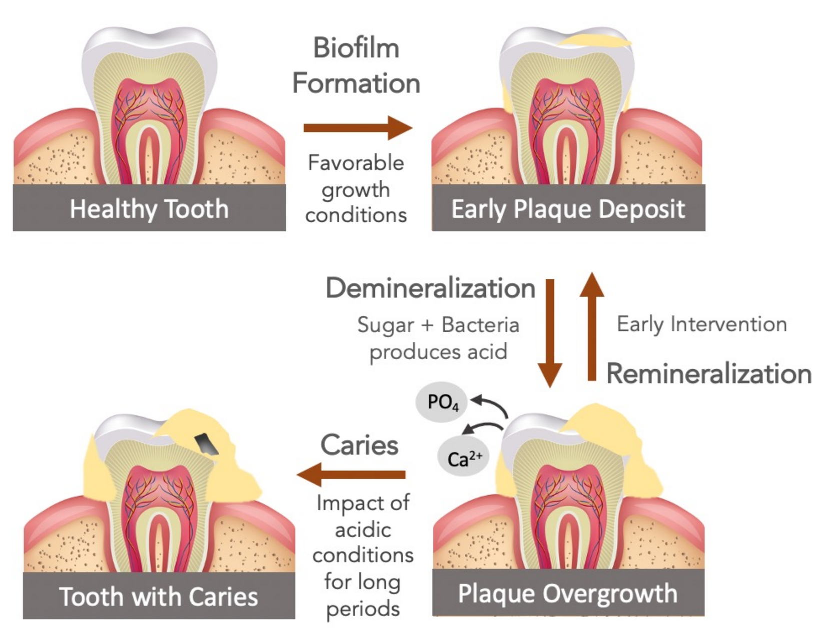
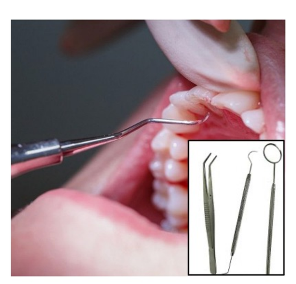
Dental Caries

Chronic caries in teeth, commonly known as tooth decay, is the most prevalent health condition affecting 2.3-3.5 billion people globally

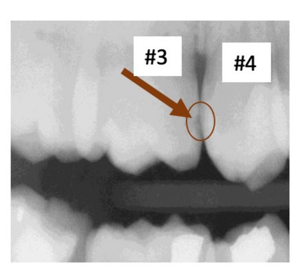
Biofilm produces acid on interaction with food which if left unmonitored can degrade the tooth enamel of minerals and ultimately cause carious cavitation.



Present tools to monitor oral health



Visualization and tactile inspection is a standard procedure to evaluate dental surfaces. These techniques are the only gold standard for detecting early caries at occlusal (biting) and smooth surfaces. Bitewing X- rays are the diagnostic tools used for caries at interproximal (in between teeth) regions.



These dental tools and procedures provide patients with **lagging, non-quantitative feedback** assisting inadequately in prevention of new caries or in evaluating site-specific risk of caries development.

There is a need to interject this present cycle of waiting-and-watching for a lesion to appear, in order to evaluate oral well-being using tools that can provide **leading indicators** for oral health.

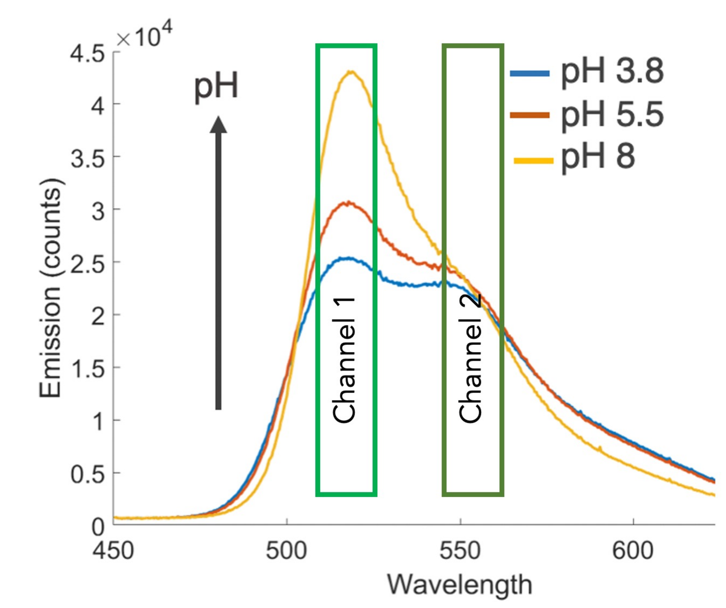
Dental Plaque Acidity: Leading Indicator

Measurement of dental biofilm pH, especially pH before and up to two hours after a sugar rinse was proposed in 1940s as shown in the Figure. Since then, several studies have examined this pH curve, commonly named as the **Stephan curve**, and found different sections of the curve: resting pH, minimum pH after the sugar rinse, time taken to return to resting pH, related to caries activity.

pH microelectrode and pH papers have been used to measure plaque pH but have several issues **limiting in clinic pH measurements.**

O-pH : Oral pH using optical sensor

An optical pH-sensor, that uses ~420 nm light to excite fluorescein dye and collects fluorescent light using fiber coupled, filtered photodiodes. It measures **pH in the range of 4-7.5**, typical pH range of the dental biofilm, with 0.97 coefficient of correlation to a standard lab pH-meter.



The device architecture consists of three components: excitation unit (blue LED), detection unit (photodiodes), and mouth probe(fiber optics).

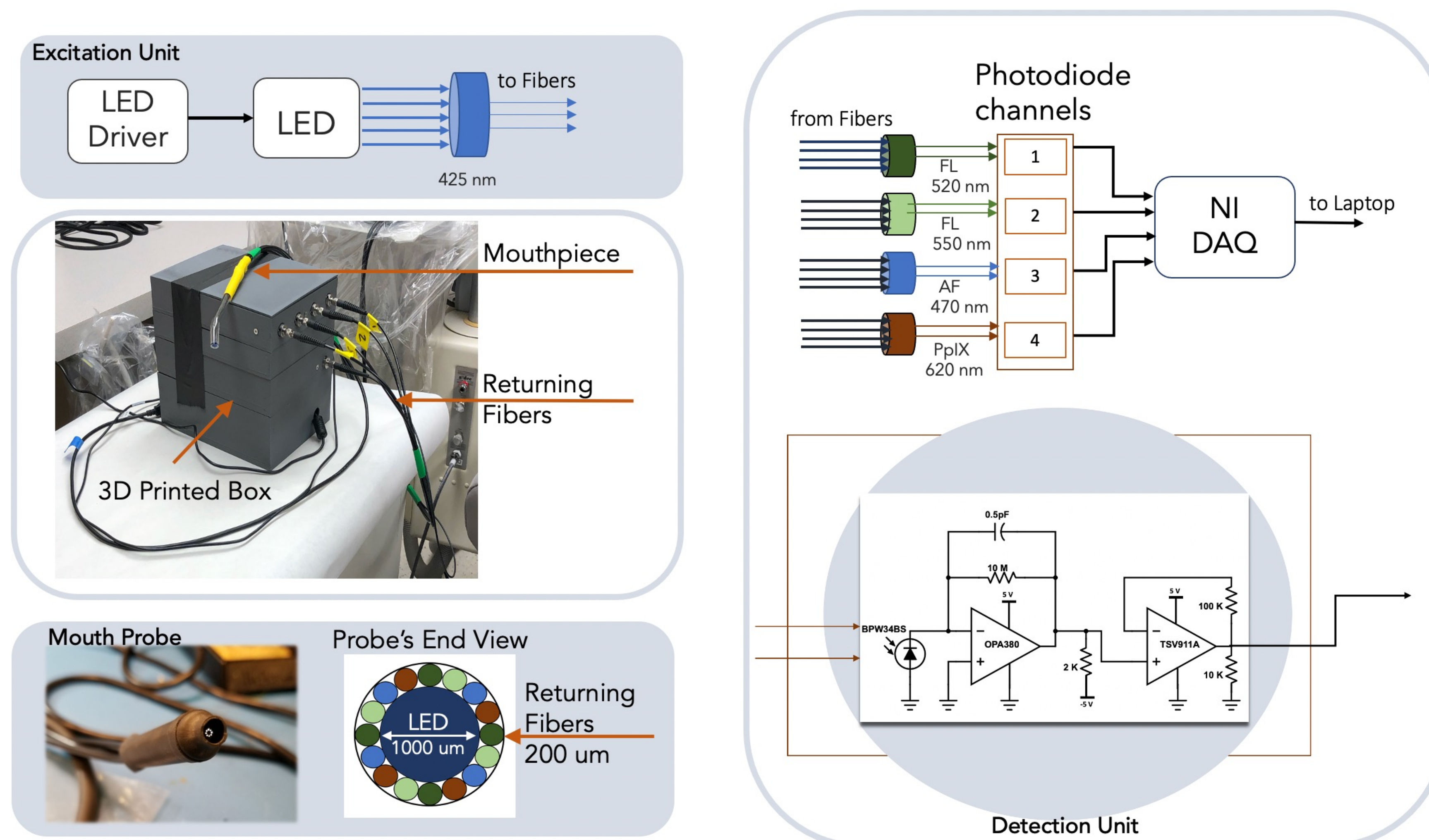
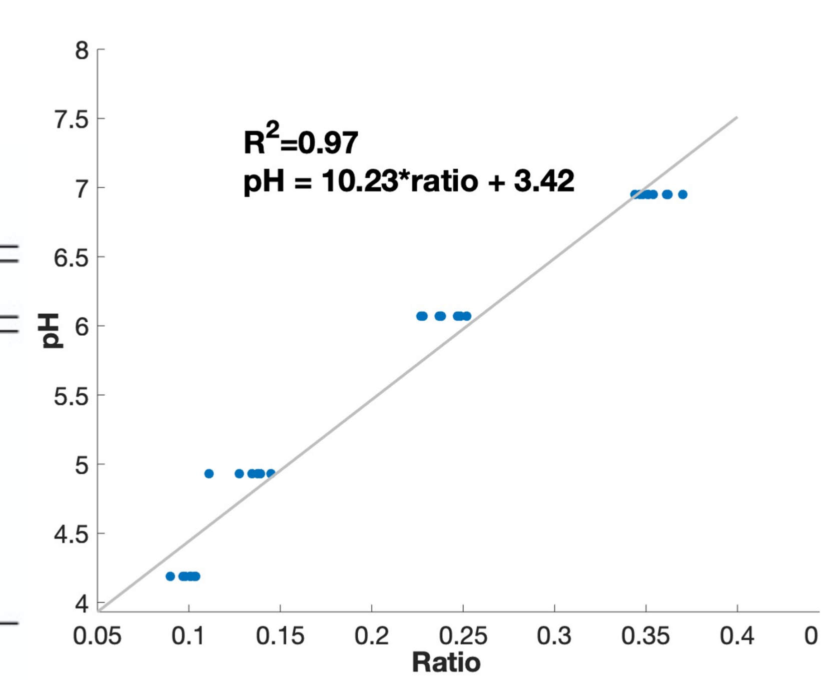


Table I: O-pH Accuracy

pH Range	Mean Error	Std Deviation
4-4.5	0.57	0.09
4.5-5.5	0.27	0.15
5.5-6.5	0.18	0.09
6.5-7.5	0.13	0.08
Overall(4.5-7.5)	0.22	0.16



Clinical Study

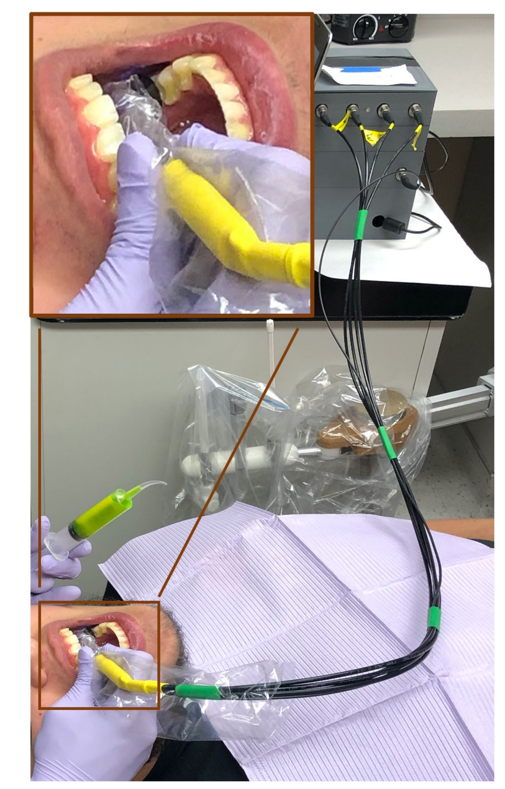


Table II: Subject Statistics

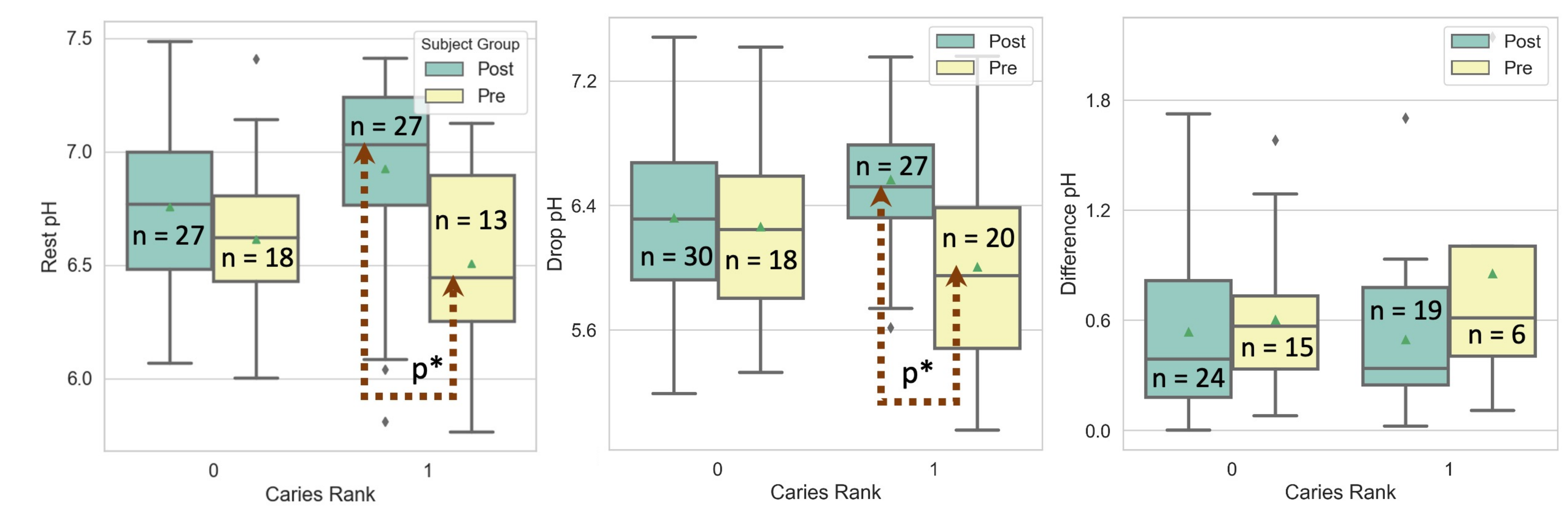
Subjects	Post-Cleaning	Pre-Cleaning	Control
Total	18	7	5
Age	16.5	15	15
Mean Cleaning Interval	31 days	114 days	14 days

The clinical study was designed with pediatric patients to monitor dental biofilm pH before and after a sugar rinse for both healthy and unhealthy teeth surfaces.

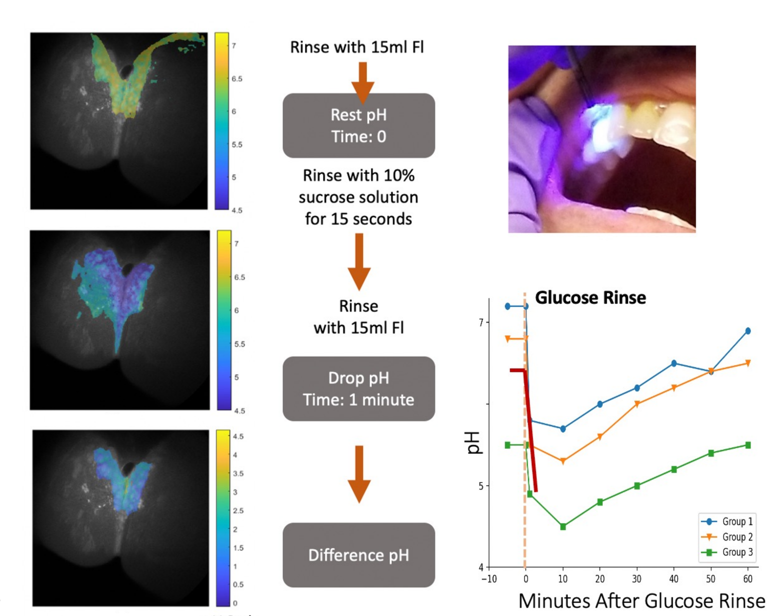
We hypothesize that **lower rest and drop pH**, and higher diff pH, are associated with **higher level of "unhealthy" dental biofilm** contributing to elevated caries risk in a certain subject.

We found Pre-Cleaning group had a lower resting and drop pH than the Post-Cleaning group. Similarly, the difference in pH was higher in Pre-cleaning group than the Post-Clean indicating higher bacterial acidification.

We also compared pH between groups with the same ranking, i.e., surfaces with rank 0 in Pre-/Post-Cleaning were compared and did not find any significant difference. For subjects with rank 1, rest pH and drop pH had a significant difference.



Towards Imaging Solution



With the present spot-based system it is difficult to perform trend analysis over short times for the Stephan Curve within a single visit, let alone months-long gaps in time across multiple visits.

These challenges can be overcome by using an **imaging system**, image co-registration, and an improved clinical protocol.

To demonstrate this concept, we modified the multi-modal Scanning Fiber Endoscope (mm-SFE) to use the two-wavelength technique employed by O-pH for optical pH image-based mapping.

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