DENTAL X-RAY
INTRAORAL
RADIOGRAPHY:
IMAGE RESOLUTION
AND PATIENT SAFETY
IN MODERN DENTISTRY

A study of film and digital sensors
DENTAL X-RAY INTRAORAL RADIOGRAPHY: IMAGE RESOLUTION AND PATIENT SAFETY IN MODERN DENTISTRY

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1 OVERVIEW AND OBJECTIVES

Digital X-Rays in the dental industry are prolific. According to a recent nationwide phone survey\(^1\), approximately 70 percent of dentists have transitioned from film X-Rays to digital.

There is no consistent gauge in the dental industry by which to measure the quality and consistency of these dental x-ray images.

Manufacturers of digital X-Ray systems claim to achieve “theoretical” resolutions of up to 33-line pairs/millimeter, while film is proven to deliver upwards of 20 LP/mm.

This research was established to answer the following questions:

- **Using a properly processed film as a control, how does digital compare in quality?**

- **Do digital X-Rays give dentists the images they need to properly diagnose their patients?**

- **What is the actual LP/mm achieved by digital X-Rays?**

- **How valuable would a standard line-pair analysis be that dentists could use for comparison-shopping when considering a new digital system?**

- **What processes do dental offices go through to ensure sterilization of dental sensors?**

\(^1\) XRS, Summer 2014
2. STERILIZATION AND PATIENT SAFETY

According to national studies\textsuperscript{2}, the plastic barrier bags used to cover digital sensors while in patients' mouths fail up to 51 percent of the time. This is a real concern for patient safety since digital sensors themselves can't be sterilized without causing damage.

Doctors and their staff rely on the plastic bags to keep patients safe, with no standard sanitization protocol in place.

The CDC admits this oversight and said in a phone conversation, “The CDC doesn’t have many protocols in place for the dental field.” In a follow-up e-mail the CDC sent a link to a report that said\textsuperscript{3}: “Digital radiography sensors and other high-technology instruments (e.g., intraoral camera, electronic periodontal probe, occlusal analyzers, and lasers) come into contact with mucous membranes and are considered semicritical devices. They should be cleaned and ideally heat-sterilized or high-level disinfected between patients.”

Quotes from doctors, when asked about sterilization techniques during this study, were as follows:

“We don’t sterilize because we use these plastic sleeves.”

“We cannot sterilize an X-Ray sensor, that would ruin it in one minute.”

“The bags we use to cover the sensor can be inserted and removed without touching the sensor. We just don't touch the sensor head when wearing dirty gloves.”

“We wipe the cable with a gentle sanitizer. Not just any sanitizer - I have seen the case of a sensor split apart because someone used Cavicide on it!”

\textsuperscript{2} Journal of the American Dental Association, April 2000
Dr. David Gane, June 2013, dentalxrays.info
\textsuperscript{3} CDC: http://www.cdc.gov/oralhealth/infectioncontrol/guidelines/index.htm
RADIATION

The average annual radiation exposure for an individual in the United States from natural sources is about 310 millirem\(^4\). A dental full mouth series (FMX) using F speed film or digital sensors typically exposes patients to about 10 millirem.

There are no guidelines for the amount of acceptable radiation exposure in the dental industry, but the American Dental Association has adapted the ALARA principle, to keep radiation exposure As Low As Reasonably Achievable.

For this study, the tester took an X-Ray of a Gendex GSX-700 sensor, the resulting image is below.

![X-Ray Image]

It's clear in this image that there is no lead barrier in the sensor protecting the patient from backscatter radiation. All intraoral film has a lead foil built in. Sensors without the lead layer do not adhere to ALARA.

Exact data wasn't gathered in this study, but it was observed that due to the ease of taking and deleting digital X-Rays, there is a real possibility of overexposing patients to unnecessary radiation in an effort to obtain clear radiographs. Again, this is not acceptable under ALARA.

SENSOR SIZE

In some patients, the size of a digital sensor does not fit into the back of the mouth, making it difficult to obtain X-Rays of the back molars. When asked how this problem is addressed, doctors said,

“Sometimes we’ll use a size 1 or 0 sensor back there.”

“Well, if we can’t take an image of the area, we skip it.”

“We do our best but sometimes the anatomy of the patient’s mouth doesn’t allow us to image the area.”

3. IMAGE RESOLUTION: TEST PATTERN AND METHODOLOGY

Twelve random dentist offices were visited in the area of Spokane, WA in October 2014. With permission, the tester took X-Ray images using a test pattern created by Fluke Biomedical, a leading manufacturer of biomedical test products. The tester used the test pattern\(^5\) and took X-Rays using the same Kv and exposure settings used in-office for taking patient X-Rays. This way, the exact results dentists achieve in their offices on a daily basis were obtained for test purposes. The test pattern was placed on the sensor and secured with tape if needed. The X-Ray tube was placed 4 cm away from the test device. Resulting digital images were sent via e-mail to the tester. This procedure was mimicked at each dental office.

Test Pattern:

![Test Pattern Image]

Fluke Biomedical test pattern, model 07-539

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\(^5\) Fluke Biomedical (Nuclear Associates) 07-539
4. LINE PAIR TESTING AND COMPARISON

This test was conducted using the same Fluke Biomedical test pattern, at K\text{v} and exposure settings used on patients. The test device was placed on top of the sensor (or film) with the X-Ray tube placed 40 mm from the test device. Twelve offices were visited, some had duplicate systems and those images are not included if there was no visible difference in the test image.

Line pairs per millimeter (LP/mm) is the best way to measure resolution in radiographs. LP/mm measure the number of black and white line pairs that will fit into a 1 mm space. Dots per square inch, or DPI, simply measures the number of digital pixels within a 1-square inch space and does not provide an accurate measurement of what can actually be seen. This study uses the LP/mm method to measure and compare image resolution.

Following are captured images, sorted by sensor brand, then magnified to show the area between 10 and 20 LP/mm.
**D-speed Film** (captured digitally by a Canon 70D shot through a Carson 10x optical loupe. In a dental office, film must be magnified using a 10x loupe on a lightbox to be viewed properly. Film showed clear past 20 LP/mm)
Schick 33 (image as captured, clear to about 11 LP/mm)

*See page 15 for advertised Schick 33 resolution claims.
Dexis 601P (image as captured, clear to about 4.5 LP/mm, though distorted):
Gendex GXS-700 (image as taken, clear to about 5 LP/mm, distorted):

*See page 15 for advertised Gendex resolution claims.*
Gendex GXS-700 (different office, image as taken, clear to about 15 LP/mm):

*See page 15 for advertised Gendex resolution claims.*
Carestream RVG 6100 (image as captured, clear to about 12 LP/mm)
ScanX (Phosphor plates, image as captured, clear to about 5 LP/mm):

*See page 14 for advertised ScanX resolution claims.*
5. DOCTOR IMPRESSIONS

The dentists in this study fell into two categories after this test:

1. Convinced film is superior technology, but they have given in to digital pressure.
2. Convinced digital is better technology but admit film’s superior image quality.

All 12 doctors admitted that there was no consistent gauge in their industry by which to compare digital X-Ray systems. All 12 agreed that seeing a line-pair test is more effective than comparing X-Rays of teeth in comparing quality. All 12 said seeing a line pair test before their purchase would have helped in their decision-making and made shopping easier.

One doctor said, “There is no way to tell which is the better system, aside from what the sales rep says. I bought blind.”

Other comments:

“I recently switched to digital. Film was so much better. I'm working on a patient, I can feel the decay, I know it's there, but I can't see it on the x Ray. That didn't happen with film.”

“Let us know if there's something better. Digital sucks.”

“I was just with a patient this morning and could see some decay with my eye, then I'd look at my X-Ray and just shake my head because I couldn't see it.”

"I just spent tens of thousands of dollars on my system and I didn't have any way to compare to other systems, other than by what the salesman or company literature said. There's no gauge in this industry."

“Film might have better image quality but digital is so much more convenient. Plus, patients expect it now. It’s more of a marketing device than anything else, unfortunately.”

“I expected my system to show 33 lp/mm, because that’s what the sales rep said. I've never seen a test like this. I'm disappointed the resolution wasn't better.”

“Digital is where dentistry is going. We might as well get on board now.”
6. ADVERTISING DECEPTIONS

It is concerning that advertising for digital sensors is not regulated. Each manufacturer claims superior image quality and better resolution than film. Real-world testing proves this is not the case.

Advertising examples:

Air Techniques makes a claim that PHP offers better clarity than film:

*See page 12 for tested PHP resolution.
Gendex claims resolution of over 20 LP/mm *(See pages 9 and 10 for tested resolution)*:

The GXS-700 sensors are designed to make migrating from film, or upgrading a digital system, easier than ever. As the eighth generation digital system from Gendex, the GXS-700 comes from a strong lineage of imaging excellence, raising the performance bar for other digital sensors. From ease-of-use and portability, to enhanced acuity and sustainability, these new sensors underscore our desire and commitment to help advance your practice with innovative and affordable solutions.

Take the GXS-700 digital sensors for a ride with this interactive 360-degree image.

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**HIGH QUALITY IMAGE CAPTURE**

- Advanced CMOS sensor technology enhances image quality, elevating technical and diagnostic capabilities
- Working within a wide dynamic range of X-ray exposure settings provides consistent image quality and repeatable results
- High-performance sensor captures high resolution images, providing more than 20 visible line pairs per millimeter

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Schick33 claims “highest theoretical resolution” but doesn’t mention real resolution *(See page 7 for tested resolution)*:

Change the definition of digital diagnostics.

Gain an unprecedented level of resolution and control over digital images with the new Schick 33. Featuring the industry’s highest theoretical resolution and lowest learning curve, it will change the way you see your images — and your practice.

The NEW Schick 33 sees it your way.

Change your settings according to your specific diagnostic needs. Use Schick 33’s clinical-specific mapping feature to automatically default to presets for general dentistry, endodontics, periodontics or restorative dentistry. Create even more personal "me-sets" for you and your colleagues that can be easily saved and shared using multi-clinician practice feature.
Doctor offices then convey the same message to the public

Schick33 is the most advanced sensor in dentistry, delivering an unparalleled combination of high-resolution images, dynamic image management, and integrates with existing Schick systems.

High Resolution Imaging

Schick 33 provides [redacted] and her team with unsurpassed image quality. This new intraoral digital sensor, which has a theoretical resolution limit of 33 line pairs, the highest available on the market, is paired with newly enhanced imaging software that enables dentists to review, store and share images from a variety of clinical perspectives. This combination of enhanced hardware and software provides the dentist with the best possible image quality.

Unsurpassed Image Management Flexibility

Schick 33’s powerful image enhancement software provides [redacted] with an unprecedented level of control over enhancements and customizations to its digital images. Among its features are:
7. CONCLUSIONS AND RECOMMENDATIONS

Results of this testing suggest that the image quality of dental film X-Rays are superior to digital X-Rays.

In this test, digital systems varied in quality from 5 LP/mm to about 13 LP/mm, whereas film captured 20+ LP/mm.

Some doctors in this test were extremely unsatisfied and unable to properly diagnose their patients with their digital X-Ray technology. Others dentists felt they could see what they needed to see, but admitted film may reveal further problems.

A consistent gauge is needed in the dental industry so dentists have a tool by which to compare competing digital X-Ray sensors, and so manufacturers are held accountable for their advertised claims.

Patient safety needs to be addressed, as there is a risk of infection due to the fact that sensors cannot be sterilized and the protective baggies fail over half of the time. (Failure rate was not part of this study.) All sensors should have backscatter protection.

There is a totally false sense of security that the baggies are enough to prevent patients from being exposed to viruses or bacteria and contracting an illness. The CDC recommends that sensors be heat sterilized after each use. This didn't happen in 100 percent of the offices visited for this study.

A patient education campaign should get underway to inform consumers about the risks vs benefits of digital dentistry. Patients should be given the choice between film or digital X-Rays, along with education on the risks and benefits of both.

Much more research is needed in this area to further compare digital systems. All digital sensors should undergo testing with the Fluke test device, and the results published for all dentists, patients, and manufacturers to view.

All 12 offices expressed surprise and many were upset that their digital images did not show the resolution that they were told they would see by the sales person and the manufacturer of the digital system.