Gentueri

Non-Invasive Collection, Preservation and Processing of Biospecimens

What's Inside

Introduction

Non-invasive sample collection at home became popular with ancestry testing and grew as genetic markers became available for nutrition and other information relevant to health and well-being. The pandemic greatly increased the acceptance of biospecimen collection and testing at home, and now more diverse applications are growing in demand. For example, genetic testing companies now offer non-invasive sample collection kits for hereditary cancer tests and carrier screening. This paper examines the options for non-invasive sample collection, preservation, and processing.

Non-Invasive Sample Collection

Swabs offer a simple collection process that is quick and easy to follow. This is critical for non-invasive sample collection since it is the least controlled part of the process. If inexperienced users cannot collect an effective sample, the processing is severely compromised. The concern with swabs is developing an effective method to process the sample.

Saliva collection has become popular, but it is not customer friendly since it involves more steps to collect an effective sample, and this method cannot be used by everyone, i.e., infants and the elderly. Even with the best written instructions, errors can be easily introduced in this collection process due to the complicated procedure and number of steps which can lead to poor sample quality, and therefore increased sample failures.

If the processing issues associated with swabs could be successfully resolved, this would provide the most effective non-invasive sample collection procedure. The simplicity of collection and transport to laboratories for processing greatly reduces potential errors and improves sample quality. For this reason, we will focus on non-invasive sample collection with swabs.

Swab Biospecimen Collection

Specimen collection swabs provide an excellent, non-invasive way to collect biological samples. Using a swab to collect a sample from an object or a non-invasive oral/buccal sample from a subject is fast and easy. The right kind of swab can be found for most any application where a sample needs to be collected. However, the liquid handling instruments used to process many sample types, including samples for genetic testing, are designed to manipulate liquids, not swabs. Swabs can interfere with sample manipulation, so a process needs to be found to easily separate samples from swabs.

With today's increasing volumes of genetic testing samples, the method needs to be (a) automatable, (b) keep samples from contamination risk and (c) be able to isolate as much of the sample as possible. We also need to consider the changing needs of the market. Many of the new genomic markers being identified for new genetic tests are larger in size. The fragment size of the DNA collected in samples must also be larger in order to be useful for these new tests. Therefore, the process for isolating the sample from the swab cannot shear the DNA.

Getting More DNA Out of Your Sample

There are four considerations when determining the best way to maximize DNA extraction from swabs.

1. The swab
2. The preservation of the sample
3. The extraction procedure*
4. The method used to separate the sample from the swab

*The extraction procedure used depends on instrumentation and desired goal of DNA fragment size versus DNA yield. This is an extensive topic and will not be considered in this paper. Our focus will be on the type of swab and the method used to separate the sample from the swab.

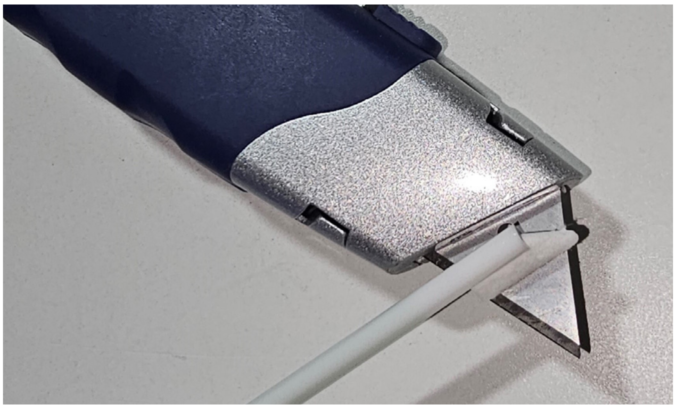
Swab Selection

There are many types of swabs that can be used to collect biospecimens for genetic testing. Potential materials for swabs include cotton, foam, plastic or synthetic fibers. Additionally, the method of how the swab material is attached to the handle can also impact its performance.

Materials

Cotton Swabs

Cotton swabs have been around for one hundred years and have proven to be the best absorbing material available by far. This helps to make collecting a robust sample fast and easy, but the current design using spun cotton is difficult to extract the sample.



Surface Sample Collection with a CollectEject Swab

Foam

Foam swabs offer another alternative for collection swabs, but they absorb considerably less sample than cotton. The lack of absorbency limits their usefulness for sample collection. Made from polyurethane, which has properties associated with cleaning applications rather than sample collection, these swabs are generally not considered.

Plastic and Synthetic Swabs

There are a few types of plastic swabs available. In 2003, the first flocked swabs were introduced. These swabs use synthetic fibers, such as nylon or polyester, which stick out from the handle to form the swab head. The concern with flock swabs is that they are hydrophobic and not very absorbent. Manufacturers have produced variations to help improve the absorbency with limited success. The main advantage of these swabs is that they are easy to extract a sample. This feature helps the processing of samples but not the more uncontrolled collection step.

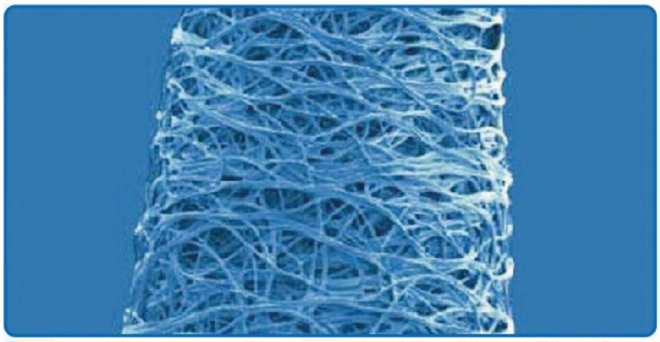
Hydrophobic polypropylene-based (plastic) swabs came to the market during the pandemic when swabs were in short supply. These swabs were initially designed for nasopharyngeal sample collection but have not had wide acceptance beyond this application.

Swab Attachment to the Handle

There are several methods to attach swab heads to the handle.

Spun Swabs

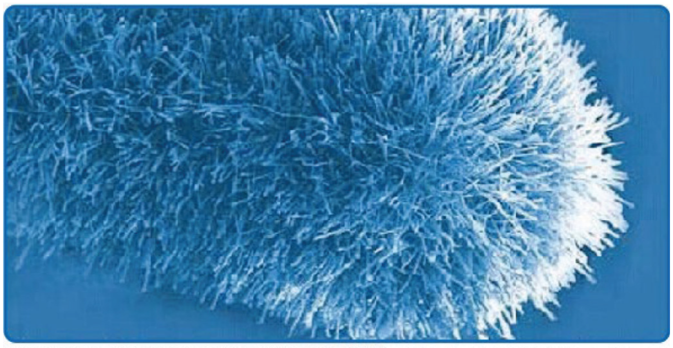
The first method developed was a spun swab head. A rope of cotton is introduced to a spinning shaft that has an adhesive. These are the least expensive swabs, with a machine producing about two thousand swabs per minute. The greatest disadvantage of spun swabs is the trapping of sample within the swab. The fibers wrapped around the shaft make it difficult to release sample from the swab.


Electron Microscope Photograph of Traditional Fiber Swab

Spun Swab

Flocked Swabs

Flocking is depositing fibers onto a surface. Manufacturers use an electric charge to stand the fibers on end to produce a swab that has synthetic fibers sticking out from the shaft. Synthetic fibers are up to half as absorbent as cotton, so the concern is the ease of collecting sufficient sample to minimize the rate of failed samples. The advantage of this design is that the straight fibers make it easy to extract the sample that has been collected.


Electron Microscope Photograph of Flocked Nylon Swab

Flocked Swab

CollectEject™ Swabs

CollectEject Swabs are a cotton swab, so they are very absorbent. However, rather than spun, they are designed like a knife blade in the shaft of the handle. The blade is made of layers of straight sheets of cotton that expand when they become wet. They are used like a very gentle toothbrush on the inside of the cheek. This separates the layers, so it becomes easy to absorb a large amount of sample, and the separated layers allow the sample to be extracted like a flocked swab. See the images below to see the various heads of spun, flocked and CollectEject Swabs.


CollectEject Oral Swab showing cotton layers

Preservation of Swabs

Once a non-invasive sample is collected at home, the next challenge is to preserve the sample until the laboratory is ready to process.

Like the collection of a sample, this part of the process is not controlled as the user needs to perform the introduction of a preservative at the point of collection before the sample is transported to the laboratory. Therefore, it is critical that this step be very simple to perform to ensure it is completed properly and samples arrive at the laboratory intact and ready to process.

For samples collected remotely, it is best to use a method that preserves samples at room temperature. This can be achieved by adding a liquid preservative or by drying or desiccating the sample.

Drying the Swab (Desiccation)

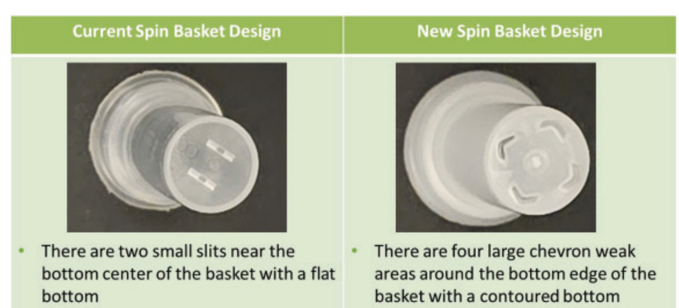
Once a swab has been used to collect a sample, it can be introduced into a container such as a pouch with a desiccant to dry the sample. This simple process has been used to collect and ship forensic biological samples for decades. It is designed to inactivate the microorganisms and enzymes that would attack the DNA, ensuring a high-quality sample for processing. The shipping of these samples is easier since you are not shipping a liquid sample that could potentially leak if not packaged properly.

Sample Processing

Labs prefer to receive samples in a solution rather than a swab since the instruments used are designed to manipulate liquids. Therefore, a sample needs to be separated from a swab to take advantage of the automated instruments used to process a sample.

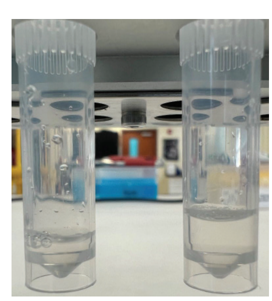
The current method to perform this separation is to centrifuge (spin) the sample after a lysis buffer has been added to the swab head that will break open the cells and release the cell contents from the swab into the solution. With the swab head in a spin basket during this process, the bottom of the spin basket is designed to open so the solution escapes to a collection tub below, while keeping the swab trapped in the spin basket. The current spin basket is designed with a flat bottom and small openings toward the center of the bottom. This design leaves a lot of sample behind and can shear the DNA.

A product coming to market called the GenSpin™ Basket solves the issues with the current spin basket.
The GenSpin is designed to be placed into a microcentrifuge tube and accepts a swab head by breaking the head off the swab, or in the case of the CollectEject Swab, the swab head is easily ejected into the GenSpin by depressing the plunger on the end of the swab. The contoured bottom of the GenSpin directs over 95% of the sample into the microcentrifuge below during centrifugation. The large chevron-shaped openings are at the outer edges of the bottom. This greatly increases the efficiency of transferring the sample from a swab into a solution ready for automated processing. This design also allows the GenSpin to be spun at less than 1,000 RCF (relative centrifugal field) rather than over 10,000 RCF as required by the current spin basket. This slower speed aids in minimizing the shearing of DNA.



Courtesy of Dr. Erik Hall laboratory Saint Louis University

Current Spin Basket elution



GenSpin Basket elution

Applications in Crime Scene Investigations and Genomics/Molecular Testing

For applications in crime scene investigations, swabs are the number one choice for evidence collection. Touch DNA samples from fingerprints or surfaces can help place a suspect at a crime location, but the amount of DNA collected is frequently too low to be detected. Improving the amount of DNA available for lab analyses can enhance the investigation process.

For applications in genomics and molecular testing, swabs are commonly used for non-invasive and self-administered collection of oral and buccal samples. Insufficient quantities of DNA can cause NGS (Next-Gen Sequencing) and PCR (Polymerase Chain Reaction) assays to fail, interrupting workflows, increasing operational costs, and negatively affecting subject experiences. Decreasing downstream failure rates can improve overall operations in genomics testing labs, saving time and money.

Conclusion

Swabs have proven to be the simplest way to collect a sample, which is critical since it is a portion of the process that is not controlled in a laboratory. CollectEject Swabs provide the absorbency of cotton and the efficient elution of a flocked swab to provide the most robust samples to reduce failure rate from non-invasively collected samples.

The new GenSpin Basket meets the needs of the changing requirements of processing samples for genetic testing. GenSpin is ethylene oxide sterilized and tested to be free from DNA, RNA, DNases and RNases (enzymes that attack DNA and RNA) to minimize any possible contamination risk to samples.

In forensic applications it can deliver up to ten times the amount of DNA compared to using a current spin basket. For genomic applications, it can deliver large volumes of larger fragments of DNA for long PCR and GWAS (Genome-Wide Association Studies) applications. The recent developments described in this paper will help improve the quality of non-invasive samples collected, which will significantly lower failure rates and provide a far better collection experience.

Centrifuging Swab Sample

"After initial testing of the GenSpin Basket the amount of liquid recovered was nearly 100% higher than a competitor's product. In turn, the amount of DNA recovered appears to be consistently higher with the GenSpin Basket. These types of increase in yield allows laboratories to ensure they are obtaining the most amount of DNA from a swab. The technology and innovation in the GenSpin Basket is important to the forensic science field as it continues to move forward."

Dr. Erik Hall
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Saint Louis University