Diabetes mellitus, commonly referred to as diabetes, is a group of chronic metabolic diseases characterized by hyperglycemia resulting from defects in insulin secretion, insulin action, or both. It is one of the oldest diseases known to man and reported in Egyptian literature dating back over 3000 years. Most cases of diabetes fall within two broad etiopathogenetic categories: Type 1 Diabetes (T1D), an autoimmune pathologic process and Type 2 Diabetes (T2D), a combination of resistance to insulin action and an inadequate compensatory insulin secretory response. In a new report from the Centers for Disease Control and Prevention (CDC) on diabetes statistics, 34.2 million people of all ages—or 10.5% of the US population—have diabetes—with an estimated 88 million people aged 18 years and older having pre-diabetes.\(^1\) This is one out of three American adults. Before people develop T2D, pre-diabetes is usually present.

In the simplest of explanations, pre-diabetes is a condition characterized by slightly elevated blood glucose levels, but not high enough to be diagnosed as T2D. Pre-diabetes can be present for years before symptoms develop. According to the CDC, of those with pre-diabetes, 90% were unaware. Pre-diabetes places patients at increased risk of developing T2D, heart disease, and stroke.\(^2\)

Type 2 Diabetes is the most common form of diabetes and according to the CDC, 90-95% of all diabetes cases in the US are T2D.\(^1\) It is a chronic condition that affects the body’s ability to metabolize glucose. The pathogenesis of T2D initiates with inadequacy of the pancreatic islet \(\beta\)-cells to respond to chronic fuel surplus resulting in increased glycemic load, insulin resistance, and obesity.\(^3\) Increased morbidity and mortality is associated with T2D. Diabetes remained the seventh leading cause of death in the US in 2017, with 83,564 death certificates listing it as the underlying cause of death, and a total of 270,702 death certificates listing diabetes as an underlying or contributing cause of death.\(^1\) Overall, the risk for death among people with diabetes is twice that of people of similar age without diabetes.

Today, diabetes remains one of the most common diseases diagnosed by family physicians, and despite scientific advances and discoveries in treating diabetes; the population diagnosed and undiagnosed continues to grow. Since the majority of cases of diabetes are T2D and the diagnostic tests are considered reliable, screening is recommended to identify asymptomatic people so lifestyle changes and medications that reduce progression and adverse sequelae of the disease can be introduced.\(^4,5\) However, there has been a recent shift in the medical model away from the yearly physical exam. Some experts argue a yearly exam does not reduce illness or mortality and think medical visits should be reserved for times of illness.\(^6\) Therefore, as dental hygienists, the protocols for diabetes screening to make the appropriate referrals should be reviewed. It can also be argued that every dental professional should provide their patient with some type of in-office screening as part of the medical history. One such tool can be found on the ADA website. This brief screening questionnaire can be printed or completed online and is available in both English and Spanish (https://diabetes.org/risk-test).
Screening for Type 2 Diabetes

Several professional organizations have made recommendations regarding screening for T2D. The US Preventive Services Task Force’s (USPSTF) current recommendation is to screen for abnormal blood glucose and T2D in non-pregnant adults 40 to 70 years of age who are overweight or obese, and repeating testing every three years if results are normal. Individuals at higher risk should have earlier and more frequent screening. Risk factors for diabetes besides weight are multifactorial and include those of African, Asian, Hispanic and Indian races and anyone regardless of race over the age of 45. In addition, if a person has a history of low HDL cholesterol, high triglycerides, and familial history of diabetes or gestational diabetes they are at an increased risk. Dental hygienists are aware that patients with periodontal disease are at an increased risk as diabetes and periodontal diseases have a bi-directional relationship. The American Diabetes Association (ADA) currently recommends screening for T2D annually in non-pregnant patients 45 years and older, or in patients younger than 45 years with major risk factors. The CDC and the American Medical Association (AMA) joined forces to create a program entitled, Prevent Diabetes STAT, advocating for screening of high-risk patients.

Pregnant women. The ADA recommends screening pregnant women in their first trimester if risk factors such as overweight, familial history and high blood pressure for developing T2D are present. The American Academy of Family Physicians and the USPSTF do not agree and recommend screening for gestational diabetes mellitus (GDM) only after 24 weeks’ gestation.

Children and Adolescents. The ADA recommends screening children and adolescents 18 years and younger for T2D and pre-diabetes who have a body mass index (BMI) greater than the 85th percentile for age and sex, weight for height greater than 85th percentile and weight for height greater than 120% of ideal. In addition, the ADA recommends screening for children and adolescents belonging to high-risk ethnic groups such as Native American, African American, Latino, Asian American or Pacific Islander as well as those with signs of insulin resistance or conditions associated with insulin resistance or a maternal history of GDM during gestation. Both the ADA and American Academy of Pediatrics recommend screening for at-risk patients every two years starting at age 10 years or at onset of puberty if before age 10.

Older adults. No organizations currently recommend routine screening of older adults, 65 years of age and older. It has been suggested that although statistics report older adults are at higher risk for pre-diabetes and T2D than any other age group, the benefits of screening older adults depends on whether or not the quality of life or life expectancy would be improved with treatment. The decision to screen or not screen should be made on an individualized basis between patient and primary care provider. When a diabetes diagnosis may lead to complications causing functional impairment, a screening should be more strongly considered in these older adults.

Testing for Diabetes

According to the ADA, patients who are clinically diagnosed with diabetes based on classic symptoms such as polydipsia, polyuria, and sudden weight loss or those having a hyperglycemic crisis, only a single diagnostic test is indicated for confirmation of diabetes diagnosis. However, those without clear symptoms of diabetes must be diagnosed using two separate and deviant test results. These tests include plasma glucose tolerance and fasting tests as well as the HbA1c test. Previously, these tests were conducted on different days. The ADA guidelines now accept two different abnormal tests on the same blood sample. If a single test is abnormal, the ADA recommends a second test for confirmation be conducted as soon as possible. The second test can be the same test repeated or a different diagnostic test altogether. Prediabetes is detected using the same tests used for detecting T1D and T2D.

Fasting Blood Glucose Test (FBG). Previously considered the gold standard of glucose tests, patients
may consume nothing but water within 8 hours of this blood test. The cut-off point for diagnosis with T2D is a blood glucose level of > 126mg/dL. A healthy person is considered to have a blood glucose level of < 100mg/dL and between 100 mg/dL and 126mg/dL is considered a diagnosis of prediabetes. It is not uncommon for this test to be conducted in conjunction with the Oral Glucose Tolerance Test (OGTT) on the same day.

**Oral Glucose Tolerance Test (OGTT).** This test measures the ability of the patient to tolerate a 75g dose of glucose after fasting. After an initial blood draw from a fasting state, the patient is given a syrupy drink containing 75g dose of anhydrous glucose. The blood glucose is measured after two hours. A diagnosis of T2D is considered > 200 mg/dL after 2 hours.

**Glycated hemoglobin (A1C) Test.** First included in the ADA guidelines as a diagnostic test for diabetes, this test measures the attachment of glucose to hemoglobin molecules in circulation. Hemoglobin is a protein found in our red blood cells that circulate oxygen. Hemoglobin also binds or glycates with glucose. When there is a lot of glucose in circulation, it is easier for the hemoglobin to become glycated. The A1c test measures the glycation of hemoglobin over a two to three-month period and is expressed as an average. There is no need for fasting. It is recommended the test be performed in a lab using a method certified by the National Glycohemoglobin Standardization Program (NGSP) utilizing testing criteria developed during the Diabetes Complications and Control Trial. Diagnosis of T2D is made at > 6.5%. It should be noted many biological factors can alter the A1c results including sickle cell diseases, anemia, hemoglobinopathies, pregnancy, HIV, and recent blood loss to name a few. The ADA does not recommend point-of-care A1C tests for screening or diagnosis. These types of chairside tests offer rapid turnaround of results, but there is a perceived inaccuracy and imprecision. A recent study found these were as accurate as lab testing.

**Random Blood Glucose Test.** This non-fasting, unplanned test may diagnose diabetes with blood glucose levels of > 200 mg/dL in conjunction with the classic symptoms of diabetes mellitus.

**Special Tests.** Because of the overlapping symptoms of the many types of diabetes mellitus, special tests may be employed to specifically diagnose rare forms of the disease. These special tests may include autoantibody testing for any or all of the following: islets cells, insulin, glutamic acid decarboxylase, insulinoma-associated antigen -2, and zinc transport. Testing for connecting peptide insulin known as C-peptide may be used to diagnose autoantibody negative type 1 diabetes and latent autoimmune diabetes in the adult (LADA). Genetic testing may be used to identify one of the many forms of monogenetic diabetes, to specify therapies to lower the cost of treatment and possibly to recognize other members of the family who may have the disease.

**Salivary Diagnostics.** One of the functions of saliva is to protect the oral cavity. Saliva helps to maintain the pH of the mouth by eliminating carbohydrates that feed the bacteria which in turn produce acids. Saliva buffers the acidity that does manage to form in the oral cavity. Other functions include lubrication, maintenance of tooth integrity, antibacterial activity, and taste and digestion. Saliva-based diagnostic technology is an emerging field and its ability to be used in screening has grown. Saliva has been reliably used to detect HIV 1 and 2, and viral hepatitis A, B and C. It can also be used to monitor a variety of drugs including marijuana, cocaine and alcohol. In the past, a major drawback to the use of saliva as a diagnostic fluid was the concern that analytes were present in lower amounts in saliva than in serum. As the field evolved, more sensitive techniques have been developed and the lower level of analytes in saliva is no longer a limitation. Some benefits of salivary diagnostics include its non-invasive nature which can decrease patient discomfort and anxiety, its low cost compared to other diagnostic procedures, and it is easy to collect, store, and ship. It has also been found that glucose can appear in the saliva of individuals with diabetes which could make salivary testing an ideal adjunctive diagnostic procedure for diabetes mellitus. The measurement of salivary
glucose can be difficult due to often low concentrations especially in patients who do not have diabetes. Measurable glucose begins to appear in saliva when blood glucose levels exceed 84.6mg/dL. Moreover, when blood glucose values reach 100mg/dL, which can be indicative of pre-diabetes, salivary concentrations of glucose can be shown to exceed 1.13mg/dL. A systematic review and meta-analysis conducted by Mascarenhas, Fatela, and Barahona confirmed a correlation between salivary glucose and glycemia (r=0.37), and salivary glucose and HbA1c (r=0.37) supporting the use of salivary glucose as a diagnostic biomarker for diabetes mellitus.

Sucrose obtained from one’s diet is cleared from the oral cavity in approximately 11 minutes whereas salivary glucose in patients with diabetes is present all day, so caution should be taken in procuring a salivary sample close to a meal as sucrose from the individual’s diet could skew results.

**Monitoring of Diabetes**

Just as early diabetes detection is critical, non-invasive methods for monitoring of diabetes are also key in ensuring patient compliance and reduction of adverse health outcomes. Those with diabetes have an increased risk of heart attack and stroke, as well as increased risk of microvascular problems such as retinopathy, neuropathy and kidney disfunction. These adverse health outcomes are postponed or decreased with strict glycemic control.

**Blood Glucose Self-Monitoring.** Blood glucose self-monitoring (BGSM) has been shown to lower a patient’s HbA1c. In a systematic review and meta-analysis of 15 clinical trials with individuals with T2D, results demonstrated that individuals who monitor their glucose compared to those who do not had a reduction in HbA1c. Currently, BGSM involves a patient pricking their finger with a lancet several times a day, applying this blood droplet to a reagent stick that is inserted into a meter to obtain the current blood glucose level. This method provides a snapshot of the blood glucose at the time of testing. Noninvasive BGSM techniques such as continuous glucose monitoring are being explored as an alternative to the finger prick test.

**Continuous Self-Monitoring.** Continuous glucose monitoring has grown in popularity among those with diabetes because it reveals short-term trends in glucose as they happen. Unlike conventional glucose meters, continuous monitoring provides semi-continuous information about glucose level via extrapolating blood glucose levels from interstitial fluid glucose via an algorithm. The patient can see the trend in their glucose levels over the last 1, 3, 6, 9, 12, or 24 hours. Continuous monitoring involves wearing a sensor placed under the skin of the abdomen or it can be adhered to the back of the arm. A transmitter on the sensor then sends the information to a wireless-pager-like monitor that the patient keeps nearby. The major players in the field are Dexcom (Figure 1), Medtronic, Freestyle Libre (Figure 2), and Eversense. The ideal sensing technology would be portable, inexpensive, and able to selectively and sensitively detect glucose with painless touch and real-time feedback.

**Tear-based Glucose monitoring.** Tear glucose concentration has a positive correlation with that in blood. Researchers have developed a

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*Figure 1: Dexom Continuous Monitoring Meter*

*Figure 2: Freestyle Libre Continuous Monitoring System*
phenylboronic acid (PBA)-based HEMA contact lens that exhibits a reversible swelling/shrinking effect to change its thickness as it absorbs glucose from tears. The difference in thickness can be detected in a picture taken with a smartphone and analyzed using software allowing the patient to monitor glucose levels (Figure 3).\(^{27}\) Researchers have also developed a hydrogel colloidal crystal that can be integrated into contact lenses that possess promising potential for noninvasive monitoring of glucose in tears.\(^{28}\)

Figure 3: Phenylboronic acid (PBA)-Based HEMA Contact Lens

**Exhaled Breath Condensate.** As an alternative to blood sample collection, exhaled breath condensate (EBC) has emerged as a promising non-invasive method to monitor glucose levels. EBC is the exhalate from breath, which has been condensed, typically via cooling using a collection device and then the glucose concentration is measured. Although most of the research with EBC has been conducted with lung cancer, emerging research has demonstrated that glucose can be detected in the collected samples. Because of the rapid glucose exchange between lung fluid and blood, the glucose concentrations gathered via EBC are typically 3–20 times lower than that of plasma glucose.\(^{29}\) A recent study with a new collection device demonstrated a higher concentration of glucose detected in the collected sample that allowed for a repeatable and robust evaluation between analytes in EBC and blood.\(^{30}\)

**Glucose Sniffing Dogs.** Emerging research suggests the use of diabetes alert dogs that are trained to detect the onset of hypoglycemia can be regarded as a fast, versatile, reliable, and cost-effective approach for safeguarding the health of those with diabetes (Figure 4).\(^{31}\) A recent review suggested that optimal performance of the dogs depended not only on good initial and ongoing training, but also careful selection of dogs for the conditions in which they will be working.\(^{32}\)

**Salivary pH.** In an effort to investigate a relationship between salivary pH and diabetes, Goyal, Kaur, Jawanda, Verma, and Parhar examined the correlation between salivary pH and caries prevalence in patients without diabetes, patients with controlled diabetes, and patients with uncontrolled diabetes.\(^{33}\) Compared to those patients without diabetes, results indicated a statistically significant decrease in salivary pH among patients with controlled diabetes (p<0.001) and those patients with uncontrolled diabetes (p<0.001), and a statistically significant increase in DMFT scores with patients with uncontrolled diabetes (p<0.002). Conversely, when comparing the DMFT score of healthy patients and patients whose glucose was in target range, there was a statistically significant decrease in dental caries (p<0.025). Lastly, upon comparing patients with controlled diabetes mellitus to those with uncontrolled diabetes mellitus, results demonstrated a statistically significant decrease in salivary pH (p<0.002) and an increase in dental caries (p<0.001) in the uncontrolled group. The authors concluded that a lower salivary pH can be caused by changes in the metabolism of patients with diabetes, however the reduction in the incidence of decay in those with controlled diabetes compared to patients without diabetes suggested that dietary control might be more significant in reducing caries than salivary pH.

The buffering capacity of saliva in patients with and without diabetes was assessed by Reddy et al.\(^{17}\) When
analyzing the initial pH versus the pH of saliva after the addition of 1.5ml HCL, patients with diabetes were found to have a sharp decline in salivary pH (6.8 to 5.3) compared to patients without diabetes (7.2 to 6.9). The authors suggested that diabetes mellitus might alter the buffering capacity of saliva leading to an increase in dental caries in patients with diabetes. It might be timely to consider the use of salivary pH as a disease biomarker for diabetes mellitus considering the results of these studies.

**Conclusion**

As new advances in diabetes diagnostics and monitoring are being made available for use, dental hygienists may encounter patients undergoing these tests and using new monitoring devices; therefore, it is important the dental professional be familiar with the available technology. Patients often rely on dental hygienists for information and as conversations regarding the patient’s diabetes diagnosis arise, these technologies might be part of the discussion.

Some dental facilities have even begun to monitor their patient’s glucose levels prior to treatment. This helps to identify patients who might be uncontrolled and might be more susceptible to complications during treatment and/or post operatively. Currently, neither the American Dental Association or American Dental Hygienists’ Association make formal recommendations on in office diagnostics and monitoring for diabetes, however, as research in salivary pH as a biomarker for diabetes continues, recommendations might be made incorporating this as a standard of care in dental practices. As the incidence of diabetes mellitus in the population continues to rise, coupled with an increase in morbidity and mortality, and costs associated with treatment, it is critical that early identification of diabetes mellitus takes place to allow for early intervention measures. As some medical practitioner’s move away from the yearly exam, dental hygienists are poised to become more involved with pre-screening to make the appropriate referrals. In addition, to avoid or delay the health complications associated with elevated blood glucose, painless and easy monitoring needs to be available. The ease of salivary testing and ability of this to be completed by the dental hygienist might make this a viable option for early detection, diagnosis and continued monitoring of diabetes mellitus.

**About the Authors**

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References

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Circle the correct answer for questions 1-10

1. Diabetes is a chronic ____________ disease.
   a) Renal
   b) Muscular
   c) Metabolic
   d) Lung

2. One out of three adult Americans has pre-diabetes.
   a) True
   b) False

3. Which of the following tests measures average blood glucose over a two to three-month span?
   a) Oral glucose tolerance test (OGTT)
   b) Hemoglobin A1c test (HbA1c)
   c) Fasting blood glucose test (FBG)
   d) Random glucose testing

4. According to the American Diabetes Association, how often should non-pregnant adults over the age of 45 be screened for diabetes?
   a) Once a year
   b) Twice a year
   c) Every five years
   d) Every three years

5. A person with no signs or symptoms of diabetes will be diagnosed using a single test.
   a) True
   b) False

6. Which glucose range is considered healthy?
   a) 1mg/dL – 50mg/dL
   b) 70mg/dL – 100mg/dL
   c) 100mg/dL – 126mg/dL
   d) 126mg/dL – 200mg/dL

7. Which of the following non-invasive glucose monitoring began in lung cancer research?
   a) Trained dog glucose monitoring
   b) Tear-based glucose monitoring
   c) Exhaled breath glucose monitoring
   d) Continuous glucose monitoring

8. Measurable glucose begins to appear in saliva when blood glucose levels exceed what level?
   a) Around 25mg/dL
   b) Around 55mg/dL
   c) Around 85mg/dL
   d) Around 165mg/dL

9. In the past, a major drawback to the use of saliva in diagnostic was:
   a) The invasive nature of collection
   b) The inability to store and ship samples
   c) The low amounts of analytes

10. Changes in metabolism in those with diabetes lowers salivary pH.
     a) True
     b) False

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