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Oral Health Measurement in Nursing Research: State of the Science

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Abstract

Oral health can impact general health and systemic disease. Changes in dental plaque, oral microbial flora, and local oral immunity may be important in the development or exacerbation of disease in critically ill patients, trauma patients, adults with chronic obstructive pulmonary disease, and frail elderly. Inasmuch as oral health potentially can be influenced by nursing interventions, nursing research in this area can contribute greatly to improved patient outcomes in these diverse populations. The authors' research teams have conducted several federally funded projects focused on oral health and have developed synergy in research methods. A unifying theme for these research projects is the measurement of oral health. Standardized measures of components of oral health are available and applicable across populations, and their uses and relationship to nursing research and patient outcomes will be discussed.

Keywords

oral health; dental plaque; saliva; microbial flora; research measurement; critical illness; elderly; chronic obstructive pulmonary disease

Oral health can have a profound effect on general health. The impact of oral health on nutrition, hydration, and quality of life is well substantiated (Hollister & Weintraub, 1993). Additionally, recent studies have suggested an association between oral health status and specific health problems, including cardiovascular diseases, glycemic control in diabetics, preterm delivery, and upper respiratory infections (Scannapieco, 1998). The significance and mechanisms of association between oral health and specific diseases, however, remain controversial. Conversely, systemic disease or disease treatments can adversely affect oral health. Oral health and its relationship to systemic health are areas of opportunity for nursing research, and oral health may be amenable to nursing interventions. Thus, measurement of specific components of oral health is an area of importance to nursing.

Nursing research in the area of oral health can contribute greatly to improved patient outcomes in diverse populations. Our research teams have conducted several federally funded projects focused on oral health and have developed synergy in research methods. In this article, we discuss measurement of salivary factors, dental plaque, and oral microbial flora as well as standardized oral health measures, which are available and applicable across populations, and their relationship to nursing research and patient outcomes.

The Oral Environment

Salivary volume and flow are important factors in oral health (Atkinson & Wu, 1994; George, 1995; Greenspan, 1996; Longman et al., 1997; Pankhurst et al., 1996; Takei et al., 1994). Saliva provides mechanical removal of plaque and microorganisms as it circulates in the oral cavity and also contains a variety of innate and specific immune components. The immune components in the saliva, including salivary IgA (an adaptive immune factor) and lactoferrin (an innate immune factor) contribute to control of the growth of microorganisms in the oral cavity (Takei et al., 1994).

Reduced salivary flow may result from inadequate hydration, poor oral care, and the use of xerostomic medications. Several medications, including anticholinergics, antihypertensives, antidepressants, diuretics, anxiolytics, and antihistamines, diminish salivary production and alter the ability of the oral environment to fight the effects of pathogens (Ettinger, 1996; Shay & Ship, 1995).

The oral cavity of a healthy individual is a microbially rich environment. The predominant aerobic oral organisms are viridans streptococci. *Streptococcus salivarius*, one of the first organisms to colonize, can be isolated from the oropharyngeal cavity of infants as soon as 18 hours after birth.

Dental plaque is a biofilm found on tooth surfaces, with as many as 700 species of organisms in communal associations embedded in bacterial and salivary products (Kolenbrander et al., 2002). Initial colonization of the tooth surfaces by bacteria occurs at the time of eruption of the child's first tooth, and in a healthy individual, the number and species of organisms in dental plaque remains relatively constant throughout that person's life. Bacterial levels can reach more than 10^{11} microorganisms per mg of dental plaque. Although the normal inhabitants of the healthy mouth are generally benign, lactic acid produced during metabolism of sugar by organisms such as *Streptococcus mutans* demineralizes tooth enamel and causes dental caries. In addition, dental plaque may serve as a reservoir for pathogens in patients with poor oral hygiene (Gipe, Donnelly, & Harris, 1995). Dental plaque of persons in the ICU, for example, has been shown to be colonized by potential respiratory pathogens such as methicillin-resistant *Staphylococcus aureus* and *Pseudomonas aeruginosa* (Scannapieco, Stewart, & Mylotte, 1992). Bacterial colonization of the oral pharynx with *S. aureus*, *Streptococcus pneumoniae*, or gram-negative rods can occur and is positively associated with the incidence of nosocomial pneumonia (Craven & Driks, 1987; Greene et al., 1994; Torres et al., 1993; Valles et al., 1995).

Oral Health Measurement in Nursing Research

Salivary Volume

Unstimulated whole saliva represents the usual, or baseline, saliva present in the oral cavity for the majority of a 24-hour period. Saliva usually flows at a rate of 0.3 to 0.65 ml/min. Stimulated salivary flow occurs when individuals eat, drink, chew gum, or brush their teeth. Stimulated saliva flow increases to 1.5 to 6.0 ml/min (Bardow et al., 2005). Hyposalivation describes flow that is less than 0.1 ml/min unstimulated or less than 0.5 ml stimulated.

Unstimulated saliva is usually obtained by having the individual sit quietly with his or her head flexed forward and allowing the saliva to passively drip from the mouth to a collection container for a specified amount of time (Hargitai, Sherman, & Strother, 2005; Johnson, Yeh, & Dodds, 2000). Alternatively, the individual can gently spit into a collection container (Chavez, Borrell, Taylor, & Ship, 2001). Stimulated saliva can be obtained using various common techniques, such as having the patient chew 1 gram of paraffin, gum, or a cotton pledget (as is used in the

Salivette collection system, Sarstedt, Numbrecht, Germany). Citric acid solutions may also be applied to the lateral aspects of the tongue to stimulate saliva production (Fischer & Ship, 1999). Less common methods include application of 5% ophthalmic pilocarpine to the patient's tongue (Rosas et al., 2002), the use of transcutaneous electric nerve stimulation devices (Hargitai et al., 2005), and the placement of sterilized marbles in the individual's mouth (Brock, Butterworth, Matthews, & Chapple, 2004). The method used must be tailored to the population being studied; for example, the use of gum, marbles, or pilocarpine may be unrealistic or unsafe in specific populations such as critically ill patients or older adults with cognitive impairments.

Proteins in saliva are primarily produced by acinar cells in the salivary glands; selected factors may also enter the saliva from the blood by diffusion or transport mechanisms. Proteins produced in salivary glands are packaged in secretory granules, which are released from the cell by exocytosis. The production of salivary proteins, the release of proteins from acinar cells, and the flow rate of saliva are influenced by a number of factors, including sympathetic and parasympathetic nervous system stimulation. Thus, the concentration of salivary factors may differ between unstimulated saliva and stimulated saliva and between different stimulated saliva samples based upon method of stimulation. Secretory release of a particular protein may or may not be related to or dependent upon salivary flow, resulting in different concentrations of some compounds in stimulated versus unstimulated saliva. Additionally, factors in blood may move into saliva via facilitated transport or diffusion across membranes, and processes that affect these transport systems will affect salivary concentration of these compounds.

Some salivary factors are found in similar amounts in unstimulated and stimulated saliva. In one study, investigators examined CD 14 (an immune recognition protein) and determined that levels were the same in unstimulated and stimulated saliva (Uehara et al., 2003). Differences have been documented, however, between stimulated and unstimulated saliva in amounts of some salivary components. Hagewald, Bernimoulin, Kottgen, and Kage (2002) found that the concentration of IgA in unstimulated saliva was almost twice that in stimulated saliva in patients with periodontal disease and in healthy controls. Brock and colleagues (2004) reported that unstimulated saliva contained less antioxidant capacity than stimulated saliva in patients with periodontal disease as well as in healthy controls.

The use of stimulated saliva samples may pose methodological problems. Stimulating agents, such as gum, may inadvertently react with the saliva and change the acid-base balance (Anderson & Orchardson, 2003). Researchers have also documented significant interference with recovery of salivary immune components in samples collected by cotton pledgets (Aufrecht et al., 1992; Shirtcliff, Granger, Schwartz, & Curran, 2001; Strazdins et al., 2005). Inasmuch as stimulating agents usually have a maximum effect within 2 min of their application (Dawes, 2005), researchers collecting saliva for a longer time period may erroneously obtain unstimulated saliva. Finally, the concentration of citric acid used to stimulate saliva is directly related to the salivary flow rate (Johnson et al., 2000).

In summary, salivary volume is an important component of the innate immune defense component of oral health. Unstimulated and stimulated saliva differ in composition for some components. Measurement of stimulated salivary volume and salivary components is influenced by the method of collection. Thus, careful planning related to the research question and accurate reporting of collection procedures are essential.

Immune Components in Saliva

Innate and adaptive immune components in the saliva provide defenses against microbial growth. Salivary immune components can be measured with commercially available immunoassay kits. Use of standardized commercial products contributes to reliability of the assays; well-developed and tested protocols are provided, and all solutions, buffers, and

reagents are provided with the assay kit. Technical assistance from the manufacturer is available for each assay online or by telephone. Colorimetric assays are available that avoid the use of radioactive substances. Reliability of the results is further enhanced by inclusion of a standard curve in each experiment. Such immunoassays are exquisitely sensitive and specific; one commercially available lactoferrin assay has a sensitivity of 1.0 ng/mL and a high specificity (observed cross-reactivity with transferrin, a closely related protein, of less than 1%) (Oxis Research Product Catalogue, 2001).

Dental Plaque

The measurement of dental plaque is frequently used as a marker of overall oral health. The original tools were developed to study the epidemiology of periodontal disease, toothbrushing efficacy, and dental health practices (Greene, 1967).

The University of Mississippi Oral Hygiene Index (UM-OHI) (Silberman et al., 1998) assesses every tooth for the presence of plaque (see Figure 1). This tool divides the oral cavity into 12 regions: left and right posterior teeth and anterior teeth in each arch, further subdivided into buccal (cheek side) and lingual (tongue side). Each tooth is then divided into five sections for the buccal surface and five sections for the lingual surface. The five sections include the mesial, distal, and middle sections (the last of which is further subdivided horizontally into gingival, middle, and occlusal sections). After staining, each section (total of 10 for each tooth) is scored for the presence or absence of plaque. If plaque definitely exists in the section, it is scored a 1; if no plaque is present, the section receives a 0. Thus, each tooth is scored from 0 (*no plaque*) to 10 (*plaque in every section*). The mean plaque score for the patient is then calculated by dividing the total score by number of teeth. Because this tool provides more information than standard tools used in dental practice, it enhances the ability to quantify plaque. Because every tooth is scored, the UM-OHI provides information about patterns of dental plaque accumulation that cannot be obtained from tools that score a subset of teeth. Interrater reliability was documented at $r = .89$, and scores for the tool were highly correlated ($r = .85$ to $.93$) with scores on standardized clinical assessment tools.

The use of disclosing agents, which are dyes that adhere to dental plaque but can be rinsed from plaque-free surfaces, increases the visibility of plaque and improves plaque-assessment accuracy. Disclosing agents that are invisible to the naked eye are useful for blinded studies, as these dyes are only visible under UV-light illumination. Other disclosing agents stain the plaque with dye that is visible to the naked eye and remain until plaque is removed.

The Oral Hygiene Index (OHI) (Greene, 1967; Greene & Vermillion, 1960) is composed of the Debris Index (which includes plaque) and Calculus Index. Each of these indices is based on 12 numerical determinations representing the amount of debris or calculus found on the buccal and lingual surfaces of each of six segments of each dental arch. Each segment is examined for debris or calculus. From each segment, one representative tooth is used for calculating the individual index. The representative tooth used for the calculation must have the greatest area covered by either debris or calculus. The debris index ranges from 0 (*no debris or stain*) to 3 (*soft debris covering more than 2/3 of the exposed tooth surface*). The calculus index has similar scoring, ranging from 0 (*no calculus present*) to 3 (*calculus covering more than 2/3 of the exposed tooth surface*). The debris and calculus scores are then each totaled and divided by the number of surfaces scored. The average debris and calculus scores are combined to obtain the OHI, which ranges from 0 to 6.

The Simplified Oral Hygiene Index (OHI-S) (Greene & Vermillion, 1964) was developed to reduce the number of decisions to be made as well as the time required for inspection (Greene, 1967). It differs from the original OHI in the number of tooth surfaces scored (6 rather than 12) and the method of selecting the surfaces to be scored. These differences, therefore, change

the properties of the scores. The six surfaces examined are selected from four specifically identified posterior teeth and two anterior teeth. The criteria used for assigning scores to the tooth surfaces are the same as those used for the OHI. The OHI-S, like the OHI, has two components, the Debris Index and the Calculus Index. Each of these indices, in turn, is based on numerical determinations representing the amount of debris or calculus found on the preselected tooth surfaces. Reliability among independent observers ranges from .72 to .94 (Blount & Stokes, 1986; Podshadley & Haley, 1968). Both the OHI and OHI-S have been used for more than 30 years in studies worldwide (Greene, 1967).

The Turesky plaque index (Turesky, Gilmore, & Glickman, 1970) was developed in 1970 and is a modification of the Quigley and Hein index (Quigley & Hein, 1962). The amount of plaque is determined with disclosing solution and scored from 0 (*no plaque*) to 5 (*plaque covering 2/3 of the crown*). The mean score per person is taken as the measure for the amount of plaque. Turesky and colleagues reported an interrater reliability correlation coefficient of .8071 but did not compare their modification of the Quigley and Hein index to the original tool or to other indices.

The Decayed, Missing, and Filled Tooth instrument (Klein, Palmer, & Knutson, 1938), which consists of visual inspection of the mouth and enumeration of decayed, missing, and filled teeth, is a classic instrument that is widely used in dental practice and research. It has been used extensively in dental epidemiologic studies since 1938, has been included in the National Health and Nutrition Examination Survey since 1960, and is part of the World Health Organization Oral Health Country/Area Profile Programme. Scores can range from a score of 0 (*all teeth present and without caries*) to a score of 32 (*every tooth evidencing dental disease through loss, active dental caries, or repaired dental disease*). The components of the instrument provide documentation of tooth loss and caries, and the summative score provides a measure of global oral health.

Oral Microbial Flora

Gram staining is widely recognized as the simplest, least expensive, and most useful of all rapid methods used to identify the presence and morphologic features of microorganisms and thus identify bacterial pathogens (Mandell, Bennett, & Dolin, 2000). However, in most cases, Gram staining does not permit definitive identification of organisms; for example, because all staphylococci will appear as Gram-positive clusters, *S. aureus* (a potential pathogen) cannot be distinguished from *S. epidermis* (a normal skin flora component). Results of the Gram stain can be affected by laboratory technique. Because of the multiple species present in the mouth, the most common Gram stain finding is “mixed respiratory flora,” reflecting the presence of usual oral inhabitants.

Cultures of microbial growth provide more specific information about microbial species and numbers. Semiquantitative cultures involve scoring the number of organisms into categories rather than direct counts of organisms. Common scoring systems employ four categories: no growth, 1+ (few), 2+ (many), or 3+ (moderate/large). Quantitative cultures are more time intensive for laboratory personnel and more expensive than semiquantitative cultures. In most instances, semiquantitative cultures provide adequate information. For example, semiquantitative cultures can provide information about the presence and relative abundance of selected species over time; such information may be sufficient for studies seeking to demonstrate the effectiveness of interventions designed to reduce the number of oral microorganisms.

When more specific information about the composition of oral flora is necessary, more technologically complex methods may be employed. DNA identification of organisms is highly reliable. Specific information about the DNA identity of selected microbial species may be

necessary to understand patterns of nosocomial acquisition or spread. For example, Garrouste-Orgeas and colleagues (1997) used pulsed field gel electrophoresis of DNA from organisms found in ICU patients to demonstrate that in 24 of 36 ICU patients, organisms isolated from the oro-pharynx prior to diagnosis of ventilator-associated pneumonia (VAP) were identical by DNA pattern to the VAP pathogen found in bronchial samples for that patient.

Choosing Oral Health Measurement Methods

Multiple options exist for nurse researchers who wish to measure oral health. The primary issue is one of validity; that is, actually capturing the components of oral health one wishes to examine.

Should a researcher collect unstimulated saliva, stimulated saliva, or both? The answer to this question depends on what aspect of salivary flow or composition the researcher is interested in investigating. Unstimulated whole saliva often yields valuable information and usually correlates to clinical conditions more accurately than stimulated saliva. For example, Bardow, Nyvad, and Nauntofte (2001) found that unstimulated saliva flow was a better predictor of tooth mineral loss than stimulated saliva flow. On the other hand, if a researcher wants to examine the effect of an activity that naturally stimulates saliva flow (such as toothbrushing) on oral immunity, then the collection and measurement of stimulated saliva might be a better choice. The population that the researcher is interested in studying may also dictate the type of saliva that should be collected. When the population under investigation is critically ill mechanically ventilated patients or severely cognitively impaired elders, the collection of stimulated saliva is not realistic and poses potential harm to patients.

We have used a variety of the techniques described in this article as measures of oral health in our own research. In our studies of the relationship of oral health to pneumonia risks associated with intubation and mechanical ventilation in critically ill subjects (Grap, Munro, Elswick, Sessler, & Ward, 2004; Munro, Grap, Hummel, Elswick, & Sessler, 2002), we measure dental plaque, salivary flow and immune components, and both oral and endotracheal microbial flora. In our studies of pneumonia risk in frail and functionally dependent nursing home elders (Jablonski, Munro, Grap, & Elswick, 2005), we use dental plaque, denture plaque, salivary flow and immune components, and both oral and denture microbial flora as outcome measures. In our research regarding exacerbations of chronic obstructive pulmonary disease (COPD), data include dental plaque, salivary volume and immune components, sputum volume and immune components, and both oral and sputum microbial flora. All of our research studies assess dental plaque using the UM-OHI because this tool enables assessment of the distribution of plaque on tooth surfaces. Understanding patterns of accumulation of plaque and the effectiveness of interventions in different areas of the mouth (for example, buccal surfaces versus lingual surfaces) may be important in designing and testing oral care interventions. In intervention studies of critically ill adults, we use plaque discloser invisible to the naked eye (UV-light sensitive) to avoid cueing study personnel who provide oral interventions. In descriptive studies of nursing home elders and patients with COPD, we use visible plaque discloser. Although all of our studies measure unstimulated salivary volume, in critically ill patients we collect saliva from the dependent sublingual pocket with a sterile disposable pipette, whereas in nursing home elders and patients with COPD, we collect saliva via passive drool. Thus, although we have commonality in oral health research interests, measures and procedures must be selected based on the research question and population of interest.

Conclusion

Researchers looking for oral health tools need to be aware of how they are operationalizing “oral health” and must be certain that the chosen instrument captures the defined attributes. A

tool developed for use with cognitively impaired institutionalized adults is probably not appropriate for measuring the oral health of toddlers or college freshmen. Feasibility is another important consideration. Collection procedures that require active participation of the patient may be difficult to implement in unconscious or uncooperative patients. Furthermore, a tool developed for use in the clinical setting as a screening instrument may lack the discrimination and refinement necessary to provide satisfactory oral health measurement in a research study.

Oral health offers a rich area of interest to nurse researchers. As the scientific foundation supporting the relationship of oral health to general health and systemic disease expands, so too must nursing interest in addressing oral health problems through nursing care interventions. Standardized tools are available, but the selection and use of oral health measures must be closely aligned to the research question. As the relationships among oral health measures and patient outcomes related to general health and systemic disease are more clearly understood, the clinical usefulness of the measures described here, or improved clinical tools for bedside assessment of oral health, will emerge.

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Figure 1. Tooth subdivisions for University of Mississippi Oral Hygiene Index (UM-OHI). Each tooth is divided into five sections for the buccal surface and five sections for the lingual surface. The tooth surface is divided longitudinally into mesial, distal, and middle sections; the middle section is further subdivided horizontally into gingival, middle, and occlusal sections. If dental plaque is present in the section, the section receives a score of 1; if no dental plaque is present, the section receives a 0

SOURCE: Adapted from Silberman and colleagues (1998), Figure 2, with permission from the American Academy of Periodontology and Dr. Stephen L. Silberman.