

Oral health and the frailty syndrome

MICHAEL I. MACENTEE & LEEANN R. DONNELLY

Frailty is neither a disease nor a disability but rather it is an age-related syndrome of increased vulnerability and decreased physical status and activity (1). It has many characteristics of diminished strength, endurance and physiologic function, compounded by a vulnerability to stressors and growing dependency on others for support with routine daily activities (44). There are numerous assessment tools for frailty that include subjective, objective and mixed measures of functional status, vulnerability and physical performance, with the ultimate aim of predicting mortality from the interaction of disability and comorbidity; however, predictions based on hazard ratios and odds ratios vary considerably (8). Nonetheless, age-associated declines in physiological function and reserve systemically compromise a person's ability to cope with stressors, which is the essential characteristic that distinguishes frailty from disability and disease (13). In this paper we will explain how frailty and its defining features influence and are influenced by oral disease and disability as people struggle to maintain homeostasis in old age.

Frailty

Cognitive and physical instability, with indistinct boundaries between social and medical demands, are essential features of frailty. They lead to falls, hospitalization, institutionalization, dependency and eventually death (57). The prevalence of frailty ranges widely, from 4 to 59% of community-based populations, in part because of different definitions and measurements of frailty (15). The Frailty Phenotype (25) and the Frailty Index (57) are the two most prominent attempts to characterize and operationalize the essential features of this condition with its loss of physical reserve (Table 1). The Frailty Phenotype characterizes frailty from a nomi-

nalist or descriptive perspective as a syndrome with at least three of the following five clinical indicators: unintentional weight loss; weak grip strength; slow walking speed; poor endurance and low energy; and low physical activity (25). It identifies also a pre-frail stage when a person has one or two of the five indicators. The Frailty Index, in contrast, offers an essentialist or mechanistic perspective to operationalize frailty as a predictor of adverse health outcomes (58). It is calculated from information gathered during a routine comprehensive geriatric assessment of acquired and age-associated health deficits and is expressed as the ratio of accumulated defects to all the possible defects that a patient could have accumulated. Indeed, frailty involves multiple dysfunctional systems, whereas disability can arise from dysfunction of a single system; and frailty is inherently unstable, whereas disability can be quite stable (57). In general, frailty increases with age and with declining health, and afflicts women more so than men, whereas disability is neither age dependent nor gender biased (2, 15, 24).

The complicated pathogenesis of frailty is slowly unraveling, with current evidence suggesting a multi-systemic etiological interaction between genetic, metabolic, environmental and behavioral factors that influences the inflammatory and immune responses to stress (13, 43). However, no association has yet been found between the levels of inflammation and incidence of frailty, and so the search continues for other pathogenic possibilities. For example, the association between disability and the loss of muscle mass and strength in old age (sarcopenia) caused by dysregulation of the musculoskeletal, immune, endocrine, hematologic and cardiovascular systems, is another, albeit no less complicated, pathogenic possibility (24, 43). In any event, each possibility can disturb the mouth and its contents.

Table 1. Definitions and clinical characteristics of frailty, and impact on oral health and oral health-care

Definition	Characteristics assessed	Impact on oral health and oral health-care
Frailty Phenotype (25)*	Unintentional weight loss of ≥ 4 kg/10 lb or $\geq 5\%$ of body weight in previous year	<ul style="list-style-type: none"> • Unstable and loose dentures • Elevated risk of caries from sugars in nutritional supplements • Candidiasis
	Weak grip strength adjusted for gender and body mass index	<ul style="list-style-type: none"> • Impaired ability to perform oral hygiene
	Slow walking speed over 4.6 m (15 feet) adjusted for gender and standing height	<ul style="list-style-type: none"> • Difficulties accessing dentistry[†]
	Poor endurance and low energy (self-reported)	<ul style="list-style-type: none"> • Inadequate oral hygiene • Difficulty accessing dentistry[†] • Intolerance to dental treatment
	Low physical activity (men < 383 kcal/week; women < 270 kcal/week)	<ul style="list-style-type: none"> • Disinterest in routine oral care • Difficulty accessing dentistry[†]
Frailty Index [‡] (58)	Medication count as deficits (0–5 medications, no deficit; 5–7 medications, one deficit; each additional three medications, one extra deficit)	<ul style="list-style-type: none"> • Salivary hypofunction • Xerostomia • Hyper-tenacious oral biofilm • Elevated risk of caries from inadequate buffering capacity of saliva • Elevated risk of mucositis, gingivitis and candidiasis • Gingival hyperplasia • Intolerance to dentures • Difficulty expressing complaints • Disregard for oral care • Difficulty accessing dentistry[†] • Inability to follow treatment regimens • Disinterest in routine oral care • Difficulty seeking oral care and treatments • Difficulty assessing oral cleanliness • Misinterpretation of therapeutic advice • Impaired ability to perform oral hygiene • Intolerance to oral care and treatments • Limited financial resources for treatment
	Cognitive status (e.g. demented, delirious)	
	Emotional status (e.g. depressed, anxious, fatigued)	
	Communication (speech, vision, hearing)	
	Strength	
	Mobility	
	Balance	
	Elimination of bowel and bladder	
	Nutrition (weight, appetite)	
	Activities of daily living (feeding, bathing dressing, toileting)	
	Instrumental activities of daily living (cooking, cleaning, shopping, medications, driving, banking)	
	Sleep	
	Social support and engagements	

*Frailty identified when three characteristics are present; and pre-frailty identified when one or two characteristics are present.

[†]Includes off-site visits to dentists, dental hygienists and other health-care providers.

[‡]Maximum number of deficits possible = 80.

Oral health in old age

Tooth loss and frailty

The aging mouth experiences changes driven by the accumulation of assaults from of a lifetime of use and exposure to oral biofilm coupled with the negative influences of systemic diseases and their management. People born before, rather than after, World War II have fewer teeth, probably because of sugar-induced dental caries, smoking-induced periodontitis and a social acceptance of complete tooth loss and replacement with dentures as a normal consequence of aging (63, 66). These behaviors and attitudes began to change a few decades after the end of World War II, with rising

affluence and programs of health promotion directed at smoking cessation and the benefits of natural teeth. Nonetheless, a large proportion of the population over 65 years of age, especially among lower socio-economic groups, wear at least one complete denture (32). Moreover, the risk of tooth loss from caries is currently as high as ever in this age group, probably because sugar is consumed frequently throughout the day by frail people who are encouraged to eat and drink constantly to avoid weight loss (69). The oral health of people who are frail is complicated further by their dependence on others for routine activities such as personal hygiene and transport. Consequently, they are predisposed to visit a dentist rarely and to assign low priority to oral health until the mouth or dental problem becomes intolerable (47).

The World Health Organization promotes a minimum of 20 healthy teeth for all age groups based on long-term evidence that a 'shortened dental arch' can meet the chewing, appearance and comfort needs of most people (35). Extreme resorption of alveolar bone after tooth extraction is very unpredictable and disabling, even when the teeth are replaced with well-made dentures, with or without endosseous oral implants. Indeed, frailty can be exacerbated quite severely following the loss of teeth if people are ill-prepared physically and emotionally to cope with this additional stress, which has been equated to the stress of marriage, retirement, grief and bereavement (6, 23). So, all-in-all, people should be encouraged to retain at least 20 natural teeth whenever possible to avoid a threat to their physical and psychological homeostasis (42, 45). Fortunately, not everyone is driven to chronic bereavement when they lose teeth, even when very frail, providing their ability to cope and adapt is reasonably intact (17).

Frail elder caries

Caries is a pathological process of prolonged acidic demineralization of tooth structure and eventual collapse of the organic matrix of the tooth. Its pathogenesis is a complicated interaction between acidogenic bacteria and refined carbohydrates within the dental biofilm, influenced internally by the structural composition of teeth and the buffering capacity of saliva and externally by the psychosocial environment and consumption of sugars and medications (4, 60). Frail Elder Caries is a rampant form of this process that destroys dentitions and causes much distress from infections and tooth loss (39). It begins when the dental matrix is demineralized for prolonged periods by acidogenic bacteria in the dental biofilm, but it spreads rampantly when medications or specific diseases inhibit the buffering capacity of saliva to neutralize the acidic biofilm. Furthermore, scars from previous carious lesions, along with the rough edges of dental restorations, provide multiple havens for bacteria to produce acids when sugar is consumed frequently. Frail Elder Caries can demineralize an entire dentition within an alarmingly short period of time (12, 26, 41). The carious process is similar on the crowns and roots of teeth, although the exposure of cementum and dentine over time usually heightens the risk of demineralization on root surfaces (22). Carious lesions range in color from light yellow through orange to black, depending on the pigments absorbed from the diet by the demineralized dental

matrix, but it is the textural appearance, rather than the color of the surface, that helps to distinguish active lesions from arrested or demineralized scars (48).

Pulpal pain

Age and environmental insults stimulate deposition of peritubular dentine inside dentinal tubules, and many of the tubules are completely obliterated and sclerosed in old age (3, 21). Dentine in the apical and mid-sections of the root has fewer tubules than elsewhere in the tooth, so pulpal stimuli through dentine on radicular surfaces are usually retarded later in life. Obliterated tubules provide neither painful stimuli nor openings for bacteria to invade the pulp, which explains why root caries can progress laterally and undetected along the roots of older teeth (11). Pain is one of the primary motivators for seeking health care, so root caries without toothache does nothing to prompt prevention and probably helps to explain why frail people are disposed more to consult a physician rather than a dentist when a low-grade pulpitis feels more like a headache or joint pain than a typical toothache (56).

Dry mouth

Xerostomia, which is the subjective symptom of a dry mouth, does not always coincide with the physical signs of salivary gland hypofunction; however, the two terms are frequently (if erroneously) used interchangeably (28). Salivary glands are disturbed by polypharmacy, radiation therapy and a few specific diseases, most notably Sjögren's syndrome, diabetes and stroke, but the effects on the flow and biochemistry of saliva are not always noticed by frail people or their physicians (68). Hyposalivation is identified as salivary flow <0.1 ml/min at rest or <0.7 ml/min when stimulated (59). Xerostomia and salivary gland hypofunction are both psychologically and physically disturbing to speech and mastication, but the hypofunction is much more life-threatening when thick accumulations of bacteria and yeasts around the mouth cause aspiration pneumonia (72).

Polypharmacy is the current scourge of old age and frailty, 'with up to 91%, 74%, and 65% of nursing home residents taking more than five, nine and 10 medications, respectively' for cardiovascular, musculoskeletal, cognitive and behavioral disorders (31). Although clinical practice guidelines for managing some disorders recommend multiple medications such as angiotensin-converting enzyme inhibitor,

beta-blocker and diuretics for congestive heart failure, the adverse effects of the medications are rarely considered or reviewed by physicians or pharmacists (9, 53).

Anticholinergics, antidepressants, antihistamines, antihypertensives, antiParkinsonians, antipsychotics, diuretics and tranquilizers all potentially disturb the quantity and quality of saliva, and their side-effects are compounded by the biochemical interactions of multiple medications. However, most practice guidelines overlook the management of polypharmacy interacting with multimorbidity, despite the prevalence of this interaction in about 50% of the US population over 65 years of age who consume three or more medications (9). There are also major (10- to 20-fold) discrepancies between warnings of dry mouth in the biomedical literature and in promotional monographs supplied by drug manufacturers (46). Consequently, dry mouth is rarely listed in the physicians' pharmacopeia as an adverse event associated with these medications, consequently most patients do not know how to manage it.

Diet

Eating and associated rituals are core characteristics of cultural behavior, and sugar dominates the eating rituals of many cultures (19). Sugar reduces pain, probably by releasing endogenous opiate, and has strong addictive properties that are difficult to break. Alterations to taste buds as a result of disease can also produce 'sweet-tooth' cravings among people who previously were relatively disinterested in sugary foods or snacks. Preferences for sweet foods increases, for example, when people with diabetes experience a drop in blood glucose levels (54). Sugar is used also to mask the bitterness of medications and to boost caloric intake against sarcopenia and weight loss. The sense of taste deteriorates in older people who are hospitalized, but less so for sugar than for sour and bitter tastes (64). All of these phenomena contribute to changing a previous disinterest in sweet foods and snacks in people as they become more frail, and are compounded by hyposalivation that adds further to a craving for sugar. The selection of food in favor of cariogenic diets is prompted also by major social change, such as hospitalization, death of a spouse, depression or disability, and, of course, loss of teeth that disturbs chewing, reduces the stimulation of salivary glands and prompts the selection of refined carbohydrates (10), particularly when people are in poor health (27).

Oral hygiene

Oral hygiene is a cornerstone of health promotion in dentistry by controlling the pathogenicity of the bio-film on teeth, oral mucosa and prostheses. It can prevent gingivitis, periodontitis and mucositis, and substantially reduces the risk of caries. Frailty can disrupt the routine of daily hygiene (38). However, oral hygiene should not be a complicated undertaking for nurses and other care staff, yet it is commonly overlooked in nursing homes – even the removal of dentures overnight to wash and dry (65) or to soak overnight in a peroxide-based cleansing solution (20). There have been many complaints about the indignities of long-term care facilities (18) but the difficulty of daily oral hygiene is widespread and apparently persistent in these institutions, despite efforts to educate administrators and staff (20, 38). Although administrators and nursing staff recognize the importance of oral health as an integral part of health care, many of them have limited skills in mouth care (30, 49, 61) probably because of many conflicting priorities-(40). Attempts to educate care staff about mouth care have been, at best, short-term, despite the potentially serious long-term consequences of neglect (16, 36, 71).

Periodontal diseases

The prevalence of gingivitis and periodontitis is unclear because of different definitions and measurement criteria for both conditions (14). About one in 10 (~11%) persons has severe periodontal disease in the form of at least one periodontal pocket of ≥ 6 mm, or >6 mm loss of attached gingiva, and the prevalence peaks at between 30 and 40 years of age (33). These estimates correspond closely to the increasing incidence of the disease among young- to middle-aged participants in the Dunedin multidisciplinary study (67). Therefore, the prevalence of severe periodontitis is not usually a major concern in old age, although the cumulative loss of periodontal support over a lifetime probably leaves older dentitions at risk of complete collapse from mild forms of the disease that afflict almost everyone who is frail and immunologically compromised (7).

Mucositis

Oral mucosa, like mucosa elsewhere, becomes thinner and less elastic with age. It shows signs of frictional keratosis when subjected to chronic trauma and signs of atrophy in people with diabetes, hyper-

tension, gastrointestinal disease and malnutrition (37, 51). Yeasts, typically *Candida albicans*, proliferate aggressively in a dry acidic environment when systemic resistance to inflammation is weak, and they form complex candida–bacterial associations that exhibit strong antimicrobial resistance (52). The candida–bacterial biofilm irritates the mucosa, typically underneath old unhygienic dentures, causing an asymptomatic stomatitis and mildly annoying angular cheilitis. Conversely, the mucositis can be extremely painful and widespread in patients receiving cancer therapy and can be very distressing especially if they had similar therapy in the past. Secondary infections of the weakened mucosa can be so virulent and painful that intense supportive care is needed, including meticulous oral hygiene. Mucositis in this context can cause interludes in the cancer therapy, along with opiate use, dietary restrictions and occasionally parenteral nutrition (70).

Mouth–body connections

Dental problems, like tooth loss, mobile teeth or toothache, disturb physical and cognitive homeostasis, and in people who are very frail, from insulin-dependent diabetes, for example, they can cause dysgeusia, gingival bleeding, enlarged parotid glands, dry mouth and candidiasis. Mucosal ulcers arise in the mouth as a side-effect of cytotoxic medications, vasodilating potassium channel activators and antithyroid drugs, while calcium-channel blockers, anti-epileptics and immunosuppressants can precipitate gingival hyperplasia (34). Similarly, a sugar-laden diet greatly enhances the risk of caries, candidiasis, stomatitis and angular cheilitis (52). So, there is no doubt that the health of the mouth influences the rest of the body or conversely, that general health influences the mouth. Yet, there is very little evidence that oral inflammatory disorders, such as gingivitis and periodontitis, influence the course of atherosclerosis, arthritis, diabetes, Alzheimer's disease or other disorders typical of frailty (50). Debate around the association between oral and systemic inflammations is complicated by the pervasive presence of comorbidity in frail people (5, 29, 55) and by the fact that aging is associated with a general elevation of inflammatory markers, such as serum interleukin-6 and C-reactive protein (62). The overall burden of multiple chronic conditions probably contributes to the course, if not necessarily the cause, of other conditions associated with frailty, and successful reduction of one disorder might improve the prognosis of the other by reducing

the overall inflammatory burden. Yet, the process by which inflammation is a common cause of many diseases, or a common pathway leading to disability and frailty, is still unknown, and the extent of the mouth–body connection as part of a modifiable risk factor remains hypothetical until the pathway is more clearly exposed.

Summary

The frailty syndrome involves multisystem dysregulation and is often characterized by at least three of the following five clinical indicators: unintentional weight loss; weak grip strength; slow walking speed; poor endurance and energy; and a low level of physical activity. It prevails in about 4–59% of the population aged 65 and older with an increased incidence in advanced age and among women. Oral health and oral health-care can be severely compromised by frailty in people who cannot attend to personal hygiene or get help from caregivers. Frailty also influences the pathogenesis of oral diseases and is influenced by oral disorders, probably through biological and environmental pathways that are linked to the common burden of inflammation. Nonetheless, the evidence is clear that oral neglect can have a very adverse effect on frailty, and depending on the type and severity of the oral condition, the consequences of the frailty syndrome can be life-threatening.

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