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Chewing sticks: timeless natural toothbrushes for oral cleansing

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It is generally accepted that oral hygiene maintenance through regular removal of dental plaque and food deposits is an essential factor in the prevention of dental caries and periodontal disease. Methods for oral hygiene vary from country to country and from culture to culture. Despite the widespread use of toothbrushes and toothpastes, natural methods of tooth cleaning using chewing sticks selected and prepared from the twigs, stems or roots from a variety of plant species have been practised for thousands of years in Asia, Africa, the Middle East and the Americas. Selected clinical studies have shown that chewing sticks, when properly used, can be as efficient as toothbrushes in removing dental plaque due to the combined effect of mechanical cleaning and enhanced salivation. It has also been suggested that antimicrobial substances that naturally protect plants against various invading microorganisms or other parasites may leach out into the oral cavity, and that these compounds may benefit the users by protection against cariogenic and periodontopathic bacteria. Some clinical epidemiological studies are in support of this, and many laboratory investigations have suggested the presence of heterogeneous antimicrobial components extractable using different chemical procedures. A few recent studies have identified some of the active antimicrobial compounds. Today, chewing sticks are still used in many developing countries because of religion and/or tradition, and because of their availability, low cost and simplicity. The World Health Organization also encourages their use. The Year 2000 Consensus Report on Oral Hygiene states that chewing sticks may have a role to play in the promotion of oral hygiene, and that evaluation of their effectiveness warrants further research.

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Chewing sticks

History

Oral hygiene measures have been practised by different populations and cultures around the world since antiquity. The evolution of the modern toothbrush has its origin in chewing sticks that were used by the Babylonians as early as 3500 BC. Ancient Greek and Roman literature discusses toothpicks that were chewed on to help clean the teeth and mouth, and many communities in developing countries still do not use conventional (modern) toothbrushes. Reasons for the continued use of traditional tooth cleaning methods include cost, availability (1), customs and religious reasons because toothbrushes are not acceptable to all Muslims as an alternative to or substitute for chewing sticks (http://www.islam.tc/Miswaak/). Therefore, chewing sticks continue to be important for oral hygiene in many Middle Eastern, African and Asian communities (2–5).

Sources and names

A variety of local trees and shrubs have been used for the preparation of chewing sticks in different parts of the world with various local names (6–8). Different plant species are selected because of their availability, long bristle-like tissue fibers and often pleasant taste. *Salvadora persica* or the Arak (synonymous with Araak) tree, known in English as the ''tooth brush tree'', the ''toothbrush tree of the Orient'' or the ''Persian tooth brush tree'', is a small upright evergreen tree or shrub with white branches and aromatic roots, seldom more than 30 cm in diameter and three meters in height (9). Geographically, *S. persica* is widely distributed: from Rajasthan (India) in the east (10) through Southern Arabia, Iran, Iraq, Israel, Egypt to Mauritania in the west and from North Africa in the north through Sudan, Ethiopia, Central Africa to South West Africa in the south (11). The roots, twigs and stems of *S. persica* have been used for centuries as oral hygiene tools (12) and are today commonly used as tooth and tongue cleaning sticks by Muslims in the Middle East, as well as in Asian and various African countries (12, 13, 4). Miswak (miswaak, misswak, miswaki, meswak, mswaki, sewak, siwak and siwaki are all synonyms used in different Arabic dialects and countries) is an Arabic word meaning tooth cleaning stick (14, 15). In English, miswak has been mentioned as ''the natural toothbrush''. In geographical regions in which the Arak tree grows, miswak is interpreted as tooth sticks prepared from *S. persica*. In areas where *S. persica* is absent, miswak is prepared from other plants. For instance, in West Africa, the lime tree (*Citrus aurantafolia*), the orange tree (*Citrus sinensis*) and senna (*Cassia sleberlanba*) are commonly used for chewing sticks (12, 13), while in the Indian subcontinent, the neem tree (*Azadirachta indica*) is widely used (16). Chewing sticks prepared from the neem tree are named ''datun'' (17). In Ethiopia, a chewing stick, generally called the ''mefaka'', is occasionally used by the majority of the population (18). *Diospyros lycioides* Desf. (Ebenaceae), known commonly as ''muthala'', is a popular chewing stick used in Namibia (19). *Rhus natalensis* and *Euclea divinorum* are plants used in Kenya as chewing sticks (20) while in Asia, the nut tree (*Juglandaceae regia*) is commonly used (21). In the United States, chewing sticks have been used by people in isolated areas of the southern part of the country, particularly in Appalachia and the Ozarks (6). These include sticks made from *Betula lenta*, *Gaultheria procumbens*, *Liquidambar styraciflua*, *Sassafras albidum* and species from *Populus* (6). Today, chewing sticks are usually made into bundles and sold in the local market. The harvesting and trade of chewing sticks threaten some plants (e.g. *Garcinia afzelii*).

Preparation

Most chewing sticks share a common design and method of preparation. Pencil-sized sticks 15–20 cm long with diameter ranging from 1 to 1.5 cm are prepared from the root, stem, twigs or bark of the specific trees or shrubs mentioned above. The stick is chewed or tapered at one end until it becomes frayed into a brush (Fig. 1). Soaking in water for a few hours will soften the natural fibers helping them to separate while tapering or chewing. The term ''chewing stick'' may therefore be misleading since the stick is chewed only briefly to fray its fibers before its common use as a toothbrush. When the mouth cleaning procedure that includes brushing of teeth, gums and tongue (Fig. 2) is completed, the chewing stick is removed from or may be left in the mouth for some additional time. Left in the mouth, the miswak will stimulate salivation and, thus, there will be a better cleansing effect. If possible, the miswak should be kept in a moist place when not in use (16). After having been used several times, the chewing stick is either replaced by a new one or its bristles are cut off to expose a fresh end where new bristles are prepared by further chewing or tapering.

The importance of miswak in Islam

Miswak should be used as recommended by the Prophet Mohammed to maintain proper oral hygiene (4). The Prophet Mohammed is therefore considered by Muslims the first dental educator in oral hygiene. However, from a religious point of view, the use of miswak has been controversial in Islam. Some Muslims considered miswak use a holy practice in which the miswak is accorded an elevated status (http://www.islam.tc/Miswaak/). Others conclude that the concept of miswak in Islam includes all oral hygiene aids and is not restricted to the use of miswak prepared from *S. persica* (15). Orthodox Muslims practise miswak tooth cleaning five times daily as an important part of ablutions before worship. Other Muslims use miswak fewer than five times a day or use a conventional toothbrush instead. It is a strong belief of some Muslims that the use of miswak has

Fig. 1. Chewing stick prepared from *Salvadora persica*. One end of the stick is frayed into a brush through chewing or tapering and is used for oral cleaning.

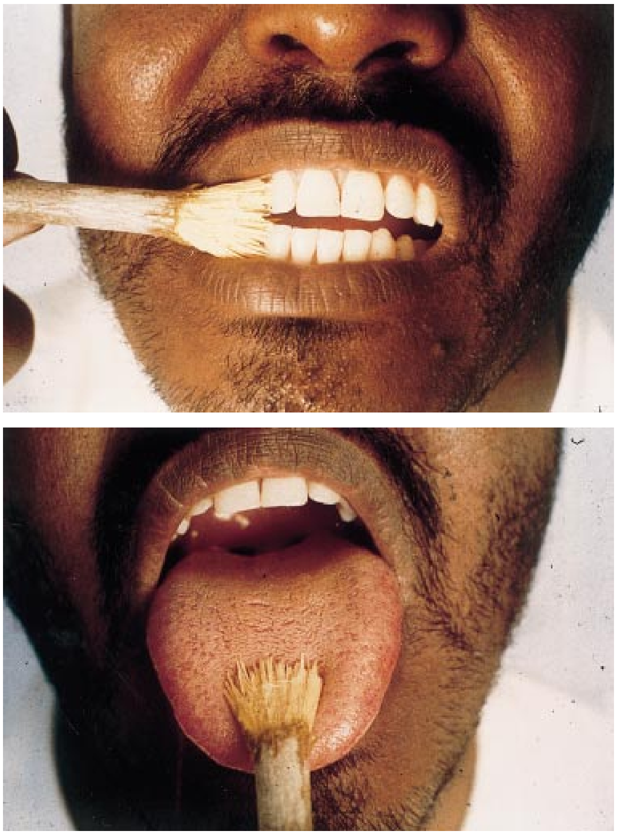

Fig. 2. Mouth cleaning with a chewing stick usually involves the brushing of teeth, gums and tongue. When cleaning is completed, the chewing stick is removed or may be left in the mouth for some additional time.

various dental and physiological beneficial effects (http://www.islam.tc/Miswaak/) (Table 1) for which scientific evidence is mostly lacking. Many children learn to use a miswak from their parents at about the age of six. Some continue to do so while others will later replace the traditional miswak with a modern toothbrush. In Saudi Arabia, many youngsters combine modern and traditional oral hygiene methods. In Pakistan, the miswak is used more among the rural than the urban population (5). Miswak appears to be more popular among the older than the younger generation and, for no clear reason, the use of miswak appears to be much more common among men than women.

Comparative mechanical efficiency of chewing sticks and toothbrushes

A recent Consensus Statement on Oral Hygiene (22) concluded that bacterial plaque plays an important role in the etiology of dental caries, gingivitis and periodontitis; that effective removal of dental plaque can result in the prevention or reduction of these diseases; that chewing sticks may play a role in the promotion of oral hygiene; and that evaluation of the effectiveness of chewing sticks requires further research. Mechanical cleaning procedures are reliable means of controlling plaque, provided cleaning is sufficiently thorough and performed at regular intervals (23, 24). In developed countries, this is achieved by tooth brushing with a manual or electric toothbrush in combination with dentifrice or toothpowder. In the developing countries, chewing sticks are often used as the sole cleansing agent (8). Since most studies on chewing sticks lack specific details concerning the duration and frequency of miswak use, it has been difficult to assess the effect miswak practice has on oral health (8). For example, Eid *et al.* (25) reported a range in the frequency of miswak use, from one or two times per day to weekly or irregular use. Gazi *et al.* (26) concluded that a miswak had to be used five times per day to significantly decrease plaque accumulation. The national health survey of Pakistan (1990–1994) showed that about 36% of the Pakistani population cleaned their teeth daily, irrespective of whether a miswak or toothbrush was employed, while 54% did so either on alternative days, weekly or monthly (5).

Various explanations for the cleansing efficacy of the miswak have been offered, including: (i) the mechanical effects of its fibers, (ii) the release of beneficial chemicals by the miswak or (iii) a combination of both (i) and (ii) (8). When a miswak is used for teeth and oral cleaning, it is held by one hand in a pen-like grip and the brush-end is used with an up-and-down or rolling motion (27, 28). A two-finger and a five-finger grip technique have also been described (29). The miswak is generally used for a longer period of time than a toothbrush (25), the cleaning is usually implemented for 5 to 10 min each time (7), and the plant fibers remove plaque and simultaneously massage the gum. Unlike a modern toothbrush, the bristles of the miswak are situated along the long axis of its handle. Consequently, the facial surfaces of the teeth can be reached more easily than the lingual surfaces or the interdental spaces (25). Reduced lingual access was considered a drawback of the miswak by Carl & Zambon (1). So far, published studies on the *in vivo* cleansing efficacy of the miswak have been scarce and such *in vitro* studies are missing. Eid *et al.* (25) reported that the majority of miswak users applied the miswak to both aspects of their teeth and no significant differences in facial plaque scores were noted between the miswak and toothbrush users in Saudi Arabia (30). Additional studies suggested miswak efficacy to be comparable with that of the conventional tootbrush (18, 31–33) or demonstrated plaque scores to be significantly lower following the use of a miswak in comparison to the conventional

Table 1. Some suggested dental and physiological beneficial effects of miswak (http://www.islam.tc/Miswaak/)

Dental	Physiological
• Strengthens gums	• Improves the sense of taste
• Effectively removes plaque	• Sharpens memory and intelligence
• Brightens teeth	• Assists in digestion
• Prevents and arrests tooth decay	• Improves the eyesight
• Cleans and brightens teeth	• Is beneficial for the health of the entire body
• Removes bad odor	• Creates lustre on the face of the continual user
• Assists in eliminating toothaches	

toothbrush used without toothpaste (26). Toothpaste used along with the miswak did not seem to enhance plaque removal efficiency of the miswak (26, 34). In a controlled study, Kenyan schoolchildren brushed their teeth for 5 min at a time using chewing sticks with or without toothpaste (34). Compared with the baseline data, the supervised brushing resulted in a net reduction of the proportion of plaque deposit sites per child that was independent of the toothpaste.

An oral hygiene assessment of primary schoolchildren in Nigeria indicated that their oral hygiene was related to the method of tooth cleaning and it was suggested that the use of chewing sticks be encouraged (35). Using the Community Periodontal Index Treatment Need (CPITN) examinations (36), Clerehugh *et al.* (37) noted relatively high mean plaque scores among 14-year-old Ghana schoolchildren, and no significant differences were detected among the three groups that used different tooth-cleaning methods: chewing sponge, chewing sticks or toothbrushes. They concluded that the children did not clean their teeth very effectively (37). A few other studies suggested that chewing sticks could be as efficient as the conventional toothbrush if proper instruction and supervision were given to the children (18, 38). In one such study, van Palenstein Helderman *et al.* (38) reported that Tanzanian schoolchildren who were miswak users exhibited significantly more plaque at baseline than did their matched toothbrush users. However, when participating in a school program that emphasized effective tooth brushing, these children were able to improve their oral hygiene regardless of whether they were habitual miswak or toothbrush users (38). While chewing sticks may effectively remove dental plaque, a positive relationship between gingival recession and the common use of miswak has been demonstrated in Saudi schoolchildren (39). Eid *et al.* (40) have also reported that miswak users had more gingival recession because of mechanical trauma than had the conventional toothbrush users.

Biological effects, antimicrobial activity, and chemical components of chewing stick extracts

Biological effects

Various studies have been performed to investigate the biological activity of chewing sticks. Extracts of *Fagara zanthoxyloides* chewing sticks were found to have anti-sickling activity of red blood cells (41). An alkaloid, fagaronine, identified from this plant has been reported to possess tumor-inhibiting properties (42). All but one out of nine Nigerian chewing stick (*Anogeissus leiocarpu*) extracts tested showed acute toxicity in mice (43, 44). Decoction of *S. persica* has been used for the treatment of splenomegaly, rheumatism, tumors, and renal stones in humans by folk medicine practitioners (45). It has also been shown to possess hypoglycemic effects, enhance plasma immunoreactive insulin level, and an incremented oral-glucose tolerance in normal rats (46). Extracts from the roots and stems of *S. persica* have been used for treatment of oral infections in animals (47). In humans, *S. persica* miswak extracts have been shown to induce morphological changes in tissue culture L929 cells (48) and IgE-mediated allergic reactions in humans (45). However, fresh plant materials from *S. persica* demonstrated no cytotoxic effect in a mammalian monolayer cell culture while cytotoxicity was demonstrated after 24 hours (49). A more recent study showed that aqueous and ethanol extracts of *S. persica* were able to remove the smear layer from the dentin surfaces (50).

Antimicrobial activity

Much effort has been expended in the examination of the antimicrobial activity of chewing stick extracts against a variety of human pathogens. Asuquo & Montefiore (51) studied eight chewing stick extracts and reported a substance from *Terminalia glaucescens* active against *Staphylococcus aureus*. Of the aqueous isobutanol and benzene extracts of five African chewing sticks tested for antibacterial activities, the isobutanol extract exhibited the greatest activity; streptococci were the most sensitive of the bacteria examined, and *Escherichia coli* the most resistant one (52). Chewing sticks from Togo have also demonstrated antimicrobial activities (53). Taiwo *et al.* (54) showed that aqueous extracts from most of the ten Nigerian chewing sticks examined contained antibacterial activities against various microorganisms including periodontal pathogens; some even had potent activities against methicillin-resistant *S. aureus*, vancomycin-resistant *Enterococcus* and multidrug-resistant *Pseudomonas aeruginosa*. The antibacterial activity of ethanol/benzene extracts from several tropical plants used for chewing sticks were found to vary with the plant species and to be target-microbe specific (55).

Although there has been an increase in the number of reports on clinical surveys and epidemiological studies of chewing sticks and their oral health benefits, relatively few studies have looked into the antimicrobial effect of chewing stick extracts against oral pathogens associated with caries and periodontal disease. Brown & Jacobs (56) noted strong antimicrobial activity of water extracts from several African chewing sticks against oral streptococci, with those from "paku" and "sackara" being the most potent. Wolinsky & Sote (57) examined the effect of aqueous extracts from eight Nigerian chewing sticks against growth and adherence of the cariogenic organism *Streptococcus mutans*. They found that an extract from *Serindeia warneckei* demonstrated the strongest inhibitory activity and proposed that tannin-like, heat-stable substances might be involved in the inhibitory activity. However, no chemical evidence was provided. Subsequent work on *S. warneckei* by Salako (58) showed that aqueous and tannic extracts of this chewing stick at concentrations of 2.5% and higher inhibited the growth of *Candida albicans* and that the inhibition was concentration-dependent. Jagtap & Karkera (21) recently investigated *J. regia* extracts and found that both the aqueous (2–8% w/v) and alcoholic (10% w/v) extracts inhibited *in vitro* growth, adherence, acid production and glucan-induced adherence of *S. mutans*. Mouth rinsing with aqueous extract of *J. regia* significantly reduced post-rinsing total streptococcal counts in salivary samples obtained up to 3 h after rinsing. The extracts also inhibited glycolytic reactions of the salivary bacteria for up to 90 min post-rinsing. However, no attempts were made to identify the active compounds present in this plant.

A few investigations have examined the effect of chewing stick extracts on growth of oral anaerobic periodontal pathogens. It was found that black-pigmented *Bacteroides* species were most sensitive to extracts from selected African chewing sticks while other *Bacteroides* species appeared to be unaffected. This may explain why these pathogens were not commonly found in the gingival crevices of adult Nigerians chewing stick users (43). Subsequent *in vitro* studies (44) of nine Nigerian chewing stick extracts against periodontal pathogens indicated that *S. warneckei* produced the strongest inhibitory action. In examining the antimicrobial effect of aqueous extracts from eight Nigerian tooth-cleaning sticks on five periodontopathic bacteria (*Porphyromonas gingivalis*, *Prevotella intermedia*, *Fusobacterium nucleatum*, *Eikenella corrodens* and *Campylobacter rectus*), Sote & Wilson (59) found that extracts of all the plants except *Massularia acuminata* inhibited bacterial growth, but at different levels. Extract of *T. glaucescens* exhibited the widest spectrum of activity, but was not active against *P. gingivalis*. Besides growth inhibition, chewing stick extracts have been shown to inhibit extracellular enzyme activities of periodontal pathogens. Homer *et al.* (20) demonstrated that extracts from *R. natalensis* and *E. divinorum* inhibited extracellular peptidase and glycosidase activities of *P. gingivalis*, *P. intermedia* and *Treponema denticola*. Although none of the above studies identified the nature of the active principles, most researchers speculated that tannin-like substances might have contributed to the observed antimicrobial activity.

Wu's laboratory in recent years has focused on the search for plant-derived natural oral antimicrobial compounds, including those from chewing sticks (60–62). One such study involved muthala (*D. lycioides*), the Namibian chewing stick that was used by approximately 20% of 2394 subjects (12–44 years) reported in a national oral health survey (63). In general, these muthala users had a relatively low caries rate (64). Using antimicrobial assay-guided fractionation, Li *et al.* (65) isolated and identified two new antimicrobial binaphthalenone glycosides from methanol extract of muthala. Recently, additional research has lead to further identification of four novel antimicrobial naphthalene glycosides (diospyrosides A, B, C and D), and two known naphthoquinones (66). To our knowledge, these represent the very few studies that have provided convincing data as to the chemical and physical identities of antimicrobial compounds in a chewing stick responsible for inhibiting the *in vitro* growth and virulence factors of oral pathogens. Although it is difficult to extrapolate from *in vitro* results the likely effects in the mouth, these data may partly explain the low prevalence of dental caries and gingivitis amongst Namibian chewing stick users (67).

Salvadora persica miswak

Currently, information on the biologically active compounds contributing to the reported oral health benefits of *S. persica* miswak has been relatively limited. Chemical analysis of *S. persica* root demonstrated the presence of β-sitosterol, *m*-anisic acid (68), and elemental sulphur (69). Chlorides, salvadourea and high content of gypsum have been found in the stem (68, 70, 71). Organic compounds identified in *S. persica* included pyrrolidine, pyrrole and piperidine derivatives (72); glycosides such as salvadoside and salvadoraside (73); and flavonoids including kaempferol, quercetin, quercetrin rutin and a quercetin glucoside (74).

Ezmirly *et al.* (69) first proposed the presence of biological active compounds in *S. persica* miswak, but data supporting this proposal were not available. The substantial amount of silica detected in *S. persica* ashes has been thought to contribute to miswak's mechanical action in plaque removal (16). The potential contribution by fluoride was considered unlikely since its soluble and total content in the *S. persica* miswak, especially that released when soaked in water, was negligible (<0.07 μg/ml) (14). Benzylisothiocyanate, a component exhibiting antiviral and antimycotic activity, has been shown to inhibit *in vitro* growth and acid production by *S. mutans*, but its mode of action was not clearly delineated (75, 76). Dorner (77) has speculated that the high amount of NaCl and KCl, sulphur-containing organic substances (salvadourea and salvadorine), and an alkaloid yielding trimethylamine on hydrolytic cleavage might somehow be responsible for the observed antibacterial and gum-stimulating effects.

Some *in vitro* studies have shown that *S. persica* extracts inhibited growth of various oral aerobic and anaerobeic bacteria, and *C. albicans* (76, 78). Inhibition of *in vitro* plaque formation, growth and acid production of various cariogenic bacteria by such extracts have also been demonstrated (15). Recently, Almas & Al-Bagieh (79) found that aqueous extracts of *S. persica* bark, pulp as well as the whole miswak, were effective against various bacteria including *S. mutans*, and noted some differences in antimicrobial activities between the pulp and bark extracts. However, no inhibition of the growth of *C. albicans* was observed. As it is evident from the chemical literature, the active ingredients in miswak were most frequently extracted either in water or ethanol for further biological or antimicrobial testings. In the case of *S. persica*, it has been shown that alcoholic extracts were more antimicrobial potent than water extracts (17). As for the effect of storage on the activity of the miswak extract, a study found no noticeable difference in antimicrobial effect between fresh and one-month-old miswak (80). When extracts prepared from *S. persica* and *A. indica* (neem) chewing sticks were compared, both were able to suppress growth of *S. mutans* and *Streptococcus faecalis* at 50% concentration and the *S. persica* extract was reported to be more effective at lower concentrations (79).

A recent study by Darout *et al.* (81) showed that miswak aqueous extracts contained potential antimicrobial anionic components including chloride, sulphate, thiocyanate and nitrate. Nitrate has been reported to affect active transport of proline in *Escherichia coli* as well as aldose from *E. coli* and *S. faecalis* (82). In addition, nitrate inhibits active transport oxidative phosphorylation and oxygen uptake by *P. aeruginosa* and *S. aureus*. The fact that the high sulphate content might have attributed to the *in vitro* antimicrobial effect of miswak aqueous extract, has also been suggested (76).

Elvin-Lewis (83) has suggested that the antimicrobial effect of miswak may involve the salivary peroxidase. Darout *et al.* (81) hypothesized that thiocyanate leaching out from miswak while in the oral cavity may lead to an elevated level of salivary thiocyanate. This, in turn, may enhance the efficacy of the salivary hydrogenperoxide-peroxidase-thiocyanate system, a known antimicrobial component of human saliva (84, 85). This may partly explain the observation that adult Sudanese miswak users had significantly lower numbers of cariogenic bacteria, except *S. mutans*, in their saliva while the matched toothbrush users demonstrated lower salivary levels of periodontopathogens (Darout *et al.* 2000, unpublished observations). As there have been no available data thus far on the salivary microflora of miswak users, these data need further confirmation.

Epidemiological studies on caries and periodontal status in chewing stick users

Caries

In a dental health survey in the Sudan, Emslie (86) reported for the first time fewer caries in people using chewing sticks than in those using toothbrushes. Low caries prevalence among chewing stick users has been reported despite intake of a carbohydrate-rich diet and lack of modern dental prophylactic measures (1, 87). In general, the Namibian muthala users had a relatively low caries rate (64). In a comprehensive survey of several thousand school children in Zimbabwe, Sathananthan *et al.* (88) demonstrated that children who used chewing sticks for oral hygiene had fewer caries lesions than children who brushed their teeth with a conventional toothbrush and paste. An earlier controlled clinical study by Baghdady & Ghose (89) compared the caries prevalence between Iraqis and Sudanese schoolchildren using the WHO DMFT (diseased, missing, filled teeth) index (WHO Oral Health Survey [36]). They reported that Sudanese schoolchildren showed lower caries prevalence due to using a miswak and their diet. Similar results were noted in Saudi children aged 13 to 15 years when compared with children in Western countries (90). Again, the main preventive factor reported was miswak use by these children.

Periodontal status

Low periodontal treatment needs have been reported among Saudi adults who used miswak (91, 92). Eid *et al*. (30) reported that there was no significant difference in gingival indices or bleeding between miswak and toothbrush users. Gazi *et al*. (26), in a cross-over study, demonstrated that gingival indices were significantly lower following the use of a miswak in comparison to a conventional toothbrush used without toothpaste. Recently, Darout *et al*. (93) assessed and compared the periodontal status of adult Sudanese habitual miswak and toothbrush users. The CPI (Community Periodontal Index) (94) was used to score gingival bleeding, supragingival dental calculus, loss of attachment, and probing depth of the index teeth of each sextant. These investigators suggested that the periodontal status of the miswak users in the studied Sudanese population was better than that of toothbrush users. The efficacy of miswaks used for oral hygiene was comparable to or slightly better than that of the toothbrush. It is believed that, due to availability and low cost, miswaks should be recommended for use in motivated individuals in developing countries.

Discussions and conclusions

Resources for health care are limited in many developing countries and the need to explore and test easily available and inexpensive traditional preventive tools is recognized. The chewing stick is the traditional tool prepared from a variety of local plants. It assumes various names, has been used for tooth and oral cleansing all over the world since ancient times, and is still being used in many developing countries. Compared with the modern toothbrush which developed from the chewing stick, the latter has a very long tradition, is affordable, economical, more ecological, readily available, can be used any time and anywhere without dentifrice or toothpowder, and may last longer. Evidence also indicates that it is effective in maintaining oral hygiene. Although chewing sticks can be used by both children and adults, and have been appropriate for many societies, the strong Islamic emphasis on oral hygiene in some countries has helped to encourage the use of chewing sticks prepared from *S. persica* or *Salvadora oleoides* (95). Elvin-Lewis (12) pointed out that the use of chewing sticks may have evolved in various cultures independent of each other. The religious practice of miswak in Islam and its association with quotations from the Prophet Mohammed have been emphasized (12, 15). Whether the strong impact of Islam on the use of the miswak may also, to some extent, have biased the miswak research, is not easy to evaluate at present.

The World Health Organization (96) has recommended and encouraged the use of these sticks as an effective and alternative tool for oral hygiene. This recommendation is also consistent with the principles of the Primary Health Care Approach that focus on prevention, community participation, and the use of appropriate technology (78). However, like tooth cleaning with modern toothbrushes, chewing sticks also need to be used properly to be effective in preventing dental diseases and promoting oral health. Children should therefore be instructed at an early age in how to use chewing sticks effectively. Results of CPITN (36) and CPI (94) in adults and children in different countries indicate that chewing sticks, when used properly, are at least as efficient as modern toothbrushes in reducing dental plaque and in preventing gingival inflammation. The few studies performed in children have indicated fewer caries lesions in miswak users (88–90).

It is important to realize that the CPITN was originally intended for screening large populations groups in order to determine treatment needs and therapeutic strategies and not for describing prevalence and severity of periodontal disease. This system is, therefore, not sensitive enough to reveal true differences among population groups. Hence, good epidemiological evidence from CPITN data on the comparative effectiveness of miswak as a means to preserve periodontal health is actually not available. By using the CPI and thus recording bleeding, calculus and pocket depths separately, and by increasing the number of involved teeth, the sensitivity is considerably improved compared with that of the CPITN.

The therapeutic and prophylactic effects of chewing sticks may be due to mechanical cleansing, potential release of biologically active chemicals when used, and/or a combination of both. The substantial amount of silica detected in *S. persica* ashes has been suggested to contribute to miswak's mechanical action in plaque removal (16).

However, literature regarding the mechanical cleansing efficacy of miswak, as compared to the manual or electric toothbrushes, has been quite scarce. Current studies available frequently lack specific details concerning the time, duration and frequency of their use, which prevents meaningful assessments of the mechanical cleaning effect of miswak upon oral health (8). As the chewing stick is often left in the mouth for some time post-cleansing, the enhanced salivation may also promote better cleansing and thus maintenance of oral health.

In search of answers to the therapeutic or beneficial effects of miswak use upon oral disease prevention and health promotion, much effort has been expended in the investigation of the antimicrobial components present in these chewing sticks. However, due to the different chemical extraction techniques used, and the lack of standardization in the antimicrobial assays, it has been difficult to assess, interpret and critically analyze the published data on antimicrobial activity of chewing stick extracts against oral pathogens. Most of the available studies have failed to provide exact chemical identities of the suspected active principles. The majority of these studies speculated that tannin-like components, rather than fluoride, were responsible. In *S. persica*, benzylisothiocyanate (BIT) has been suggested (97) to play a role in its antimicrobial activity against *in vitro* growth and acid production by *S. mutans* (75, 76). However, Ezmirly & El-Nasr (98) subsequently demonstrated that BIT was actually an end product derived from enzymatic hydrolysis of the glucosinolate present in the plant. Recent attempts by Wu *et al*. (unpublished data, 2000) also failed to identify BIT from *S. persica* extract. Additional reports on the *in vitro* antimicrobial activity of *S. persica* extracts by a few authors (17, 78–80) await verification by independent researchers using other techniques. The recent identification of various novel and known oral antimicrobial compounds (i.e. naphthalene glycosides and naphthoquinones) from the Namibian chewing stick (*D. lycioides*), using specific antimicrobial assay-guided fractionation and purification procedures (65, 66) has been encouraging. These studies may provide researchers with standard procedures in the identification of active therapeutic agents in various chewing sticks.

With better understanding of the properties, clinical effectiveness, and the development of effective techniques, with emphasis on frequency and thoroughness of the cleaning, chewing sticks may well represent an equivalent or alternative instrument to the toothbrush for prevention and control of dental diseases in developing countries. Further research and controlled clinical studies/trials are warranted to better evaluate the effectiveness of chewing sticks and their oral health benefits (22).

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