

Side effects of sodium lauryl sulfate applied in toothpastes: A scoping review

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ABSTRACT: Purpose: To perform a scoping review on the available literature regarding the side effects of sodium lauryl sulfate (SLS) used in toothpastes. **Methods:** A scoping review was performed according to the PRISMA extension using PubMed. The electronic search was supplemented with a manual search for a complete overview. A customized data collection form was used to map data which was developed to register the extracted relevant data. The results of the selected articles were classified according to effects in the mouth, on the mucous membrane or elsewhere in the body and the healing effects of SLS-free toothpaste on aphthous ulcers. The outcomes from each category were reported in separate data forms and the studies with incomplete information were excluded from the assessment. **Results:** Possible harmful effects of SLS were reported as mucosal desquamation, irritation or inflammation of oral mucosa or the dorsal part of the tongue, ulcerations, and toxic reactions in the oral cavity. (*Am J Dent* 2022;35:84-88).

CLINICAL SIGNIFICANCE: There is limited evidence that patients with recurrent aphthous ulcers can benefit from the use of SLS-free toothpastes in terms of decrease in the number of ulcerations, duration of the ulcerations and the intensity of the pain caused by the ulcerations. It is essential to create awareness for the side effects of SLS in toothpastes but further research is needed on its effect on oral and gastrointestinal systems when used in toothpastes.

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Introduction

The greatest improvement in oral health that has taken place in The Netherlands is the increase in attention paid to improving oral hygiene. Initially, this only involved brushing teeth with tooth powder or toothpaste but later that was complemented with introduction of fluoridated toothpaste. Since then, many toothpastes have been developed with different claims about their effect. The addition of fluoride to the toothpastes is probably the most effective measure in progress in oral health over the past 50 years.¹⁻³

Today's toothpastes have become complex healthcare products and often contain more than 20 ingredients. Among these, there are formulation excipients and therapeutic or other substances integrated with the aim of combating a variety of oral diseases and conditions while providing also cosmetic benefits.³

The use of oral hygiene products ('oral cosmetics') including toothpaste is recommended by almost every oral healthcare professional. Despite the superior quality, some individuals cannot tolerate some toothpastes as they may contain components causing toxic or allergic reaction.¹ Most reported reactions to toothpaste relate to contact dermatitis of the mouth and face.⁴⁻⁶ Symptoms of contact dermatitis can appear either as ulcers in the mouth, swollen gums, an irritated tongue, or itching and exfoliation of the lips and skin around the mouth.⁷

In Europe, toothpastes are covered by the European Cosmetics Legislation unless they contain a substance, such as high amounts of fluoride which then falls under the legislation of medicine. For cosmetics, a comparatively easy assessment of biocompatibility is required. Typically, advertising claims are better investigated than the possible unwanted side effects as competitors may litigate each other for unproven claims. Thus, producing a good toothpaste is not as easy as it seems. Toothpastes should not only fulfil the intended effect and have a long shelf life but should also taste good, give a fresh feeling

Table 1. Co-formulations in toothpastes.

Co-formulation aids	Intended purpose
Viscosity modifier	Ensure that the toothpaste has and retains a paste-like consistency
Humidifiers	To maintain moisture and prevent toothpaste from drying out due to exposure to air
Flavors/sweeteners/fragrances	To make the toothpaste taste appealing
Colors	To make the appearance more attractive
Preservatives	To prevent the growth of microorganisms in the toothpaste

and above all be resistant to contamination with the many microorganisms on the toothbrush.

Overall, the components that make up a toothpaste can be divided into two categories. In addition to the 'co-formulations' that form the basis for making a paste (Table 1), 'active ingredients' or 'therapeutic excipients' are added that are intended to promote the therapeutic effects of the toothpaste (Table 2). In this case, preservatives are also included in the excipients.

Almost all categories of such preservatives may contain substances which may cause side effects in some individuals.⁸ One such common ingredient is the surfactant sodium lauryl sulfate (SLS) which is a detergent also known as sodium dodecyl sulfate, an anionic surfactant found in many toiletries and cosmetics, that is mainly chosen as an ingredient for toothpastes due to its effective cleansing and foaming effect, which helps avoid particles sticking to the tooth tissue during brushing and can then be easily washed away. Despite these essential effects, SLS can irritate the mucous membranes even in low quantities and cause type IV allergic reactions.^{9,10} SLS dilutes the mucus, making mucous membranes less protected and more permeable.¹¹ SLS is not only a common ingredient of toothpastes but also a basic ingredient of shampoos. Since SLS

Table 2. Active ingredients in toothpastes (also the claim of the manufacturer).

Active ingredients	Intended purpose
Anti-caries agents	Prevent caries development
Anti-plaque agents	Prevent plaque development
Antigingivitis agents	Prevent the development of gingivitis
Fragrances	Prevent bad mouth odors
Anti-tooth stone agents	Prevent tartar development
Erosion prevention agents	Prevent erosion
Remineralization promoting agents	Promote remineralization
Means for tooth sensitivity	Reduce tooth sensitivity
Bleaching agents	Teeth whitening
Anti-xerostomia agents	Prevent mouth dryness
Other means for soft tissues (e.g., aloe vera or coconut leaves etc.)	Healing effect for soft tissue (aphthous ulcers, etc.)
Detergents/surfactant	A soapy effect to ensure that the brushed particles do not stick to the tooth tissue and can be washed away
Abrasives	Mineral powder with an abrasive effect to remove discolorations such as stains due to smoking on the surface

Table 3. The search terms used, filters applied and number of hits.

Keywords	Filters	Result
(Sodium lauryl sulfate) AND (adverse reactions)	Human, English, Dutch, Full text	275
(Sodium lauryl sulfate) AND (aphthous stomatitis)	Human, English, Dutch, Full text	15
(Sodium lauryl sulfate) AND (aphthous stomatitis OR adverse reactions)	Human, English, Dutch, Full text	238
(Sodium lauryl sulfate) AND (sensitization)	Human, English, Dutch, Full text	187
(Sodium lauryl sulfate) AND (toxicity) AND (dentifrice)	Human, English, Dutch, Full text	8
(Sodium lauryl sulfate) AND (allergies) AND (dentifrice)	Human, English, Dutch, Full text	5
(Sodium lauryl sulfate) AND (adverse reactions) AND (toothpaste OR dentifrice OR oral rinses)	Human, English, Dutch, Full text	14

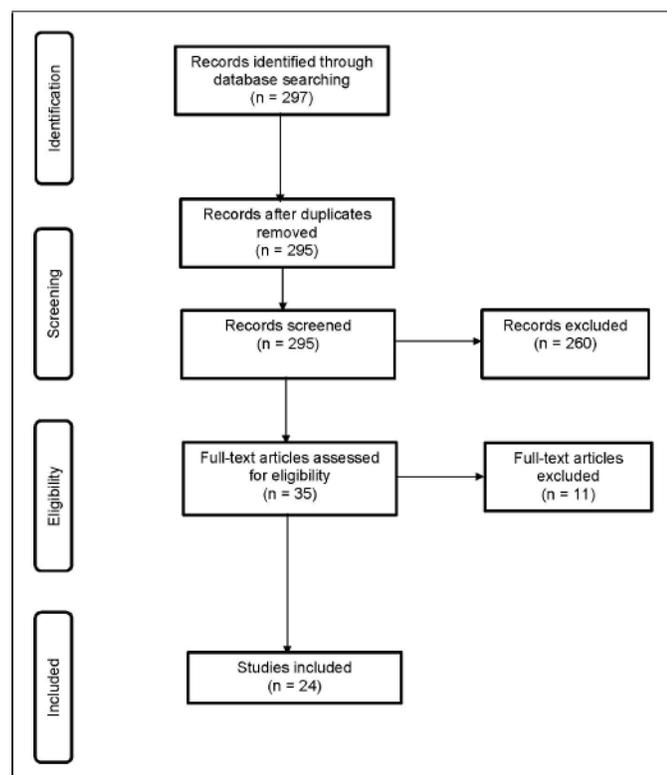


Figure. Flow diagram of the study.

may irritate the eyes, other less irritating detergents are used in baby shampoos. It is also claimed that SLS-free toothpastes help wounds to heal faster in patients with aphthous lesions.¹²

Therefore, this scoping review addressed the research question on the possible side effects of SLS in the oral cavity or the body when incorporated in the toothpastes.

Materials and Methods

Protocol - In this study, due to the lack of randomized controlled trials, a scoping review type was chosen to identify and map the types of available evidence. This scoping review was prepared according to the PRISMA extension for scoping reviews (Figure). PubMed was consulted to systematically search for the available literature (Table 3). The search was limited within a period between February 2020 and March 2021. The electronic search was supplemented with manual search for a complete overview. The search by hand was carried out using 'similar articles' to the articles found via electronic search at PubMed.

Studies were included if they met the following criteria:

- Reporting on the health effects of SLS.
- Reporting on the side effects of SLS.
- Articles in English.
- Retrospective, prospective, observational, cross sectional or cohort studies and case reports.

Studies were excluded based on the following criteria:

- Animal studies.
- Relevance.
- Lack of scientific evidence.
- If no information was present about SLS.

Selection of sources - One researcher screened the relevant articles. Initially, the titles of all articles were assessed for relevance. Abstracts were then screened based on the eligibility criteria, followed by the assessment of the full text publications.

Mapping data - The results of the selected articles were classified according to effects in the mouth, on the mucous membrane or elsewhere in the body and the healing effects of SLS-free toothpaste on aphthous ulcers. A customized data collection form was used to map data, which was developed to register

the extracted relevant data. The outcomes from each category were reported in separate data forms and the studies with incomplete information were excluded from the assessment.

Results

The results of the literature review are classified distinguishing between external and internal exposure, including an exposure by toothpaste to SLS (Tables 4-6). The exposure of SLS via toothpaste intraorally through the mucous membranes goes into the body or the gastrointestinal system through swallowing, resulting in local or systemic effects. Furthermore, a distinction could also be made on the influence of SLS on hard or soft tissues. Exposure to the soft tissues intra-orally was divided into exposure through the tongue or mucosa.

Evaluation of the selected articles - A reaction caused by SLS did not differ significantly between individuals with healthy skin and those with psoriasis or hives.¹³ Six studies¹⁴⁻¹⁹ were identified reporting on the effect of SLS on the skin. SLS is an irritant that affects the skin barrier, and the grade of irritation increases with the concentration of SLS.^{14,15} Acute skin irritation by SLS gives the same results in both atopic and non-atopic skin¹⁶ but individuals who tend to have skin irritation are also more susceptible to develop an allergic skin reaction.¹⁷

Participants with white skin showed more severe clinical reactions than those with black skin. Reflectance confocal microscopy findings revealed microscopic changes even without clinical evidence of irritation. Confocal features included parakeratosis, spongiosis, perivascular inflammatory infiltrate and formation of macrovesicles, which were also confirmed by histological findings. Also, participants with fair skin presented more increases in trans-epidermal water loss after exposure to 4% SLS than those with dark skin.¹⁸

Twelve studies^{7,11,19-28} evaluated the effects of SLS in toothpastes.

When using SLS containing mouthwash, only about 4% of the amount of SLS was found left in the mouth 2 minutes after rinsing. The amount of SLS that was left in the mouth after brushing with SLS containing toothpaste was 38% immediately after 15 seconds of brushing, 20% after 10 minutes and 2% after about 2 hours. On the other hand, 26% of the SLS was left on the toothbrush after brushing.²³

SLS is an anionic cleanser used in most of the oral care products. It is a recognized skin irritant and may further disrupt the healthy oral epithelium, thereby increasing the susceptibility to recurrent aphthous stomatitis. Although the data are not entirely unambiguous, several studies have suggested that the use of toothpaste with SLS may be associated with an increased frequency of recurrence, pain intensity and prolonged healing time of aphthous ulcers. One case report²⁷ suggested that patients with recurrent aphthous stomatitis may potentially benefit when they avoid using toothpastes containing SLS. In a double-blind crossover clinical study,²⁹ significantly higher frequency of aphthous ulcers was demonstrated when the patients brushed their teeth with an SLS-containing toothpaste compared to those containing cocamidopropyl betaine (CAPB) or a detergent-free placebo paste. Accordingly, an SLS-free toothpaste was recommended for patients with recurrent aphthous ulcers.²⁹

Table 4. Possible symptoms by SLS due to external exposure.

	External exposure
SLS	Skin irritation ³⁷ Eye irritation ³⁸ Hair loss ³⁹ Eczema ⁴⁰

Table 5. Possible symptoms of SLS with due to internal exposure

	Internal exposure
SLS	Organ toxicity ⁴¹ Mutagenicity ⁴²

Table 6. Possible symptoms of SLS in intra-oral exposure to toothpastes.

	Exposure by toothpastes
SLS	Mucosal desquamation ^{28,43} Irritation or inflammation of oral mucous membranes ^{9,28,42,44} Ulcerations ^{28,43-45} Oral toxicity ^{46,47} Inflammatory reactions of the dorsal tongue ²¹ Burning mouth sensation ^{28,43,45}

In another study,²⁸ SLS in toothpastes resulted in significantly more desquamation ($P < 0.04$, $P < 0.001$, $P < 0.001$) for SLS concentrations of 0.5, 1 and 1.5%, respectively compared to detergent-free toothpastes. Toothpastes with SLS resulted in significantly more desquamation ($P < 0.001$) compared to those with CAPB as detergent. When using toothpastes with SLS, significantly more epithelial cell flakes were observed in saliva compared to toothpastes with CAPB as detergent or without detergent. Furthermore, after using an SLS-containing toothpaste, burning or itchy feeling was more often reported.

In two studies,^{11,29} it was emphasized that SLS caused mild inflammatory reactions on the skin in low concentrations ($< 1\%$) and more pronounced inflammatory reactions in higher concentrations ($> 1\%$). The oral mucosa is more vulnerable than the skin. In toothpastes, the concentration of SLS varies between 1-3%.¹¹ Epithelial cells exposed to a low concentration of SLS (0.015%) showed normal architecture of epithelial cells and less defined epithelial cell compartments⁷ compared to epithelial cells not exposed to the low concentration of SLS ($P = 0.016$).^{11,30} Furthermore, during exposure to SLS, stratum spinosum cells presented an apoptotic morphology. Tissues exposed to a higher concentration of SLS ($> 0.15\%$) showed a decrease in epithelial thickness ($P = 0.003$) because cells were released from the epithelial surface. A clear destructive effect was observed with SLS concentration of $> 0.5\%$, in the form of apoptosis and necrosis of the upper half of the epithelium. SLS stimulates the proliferation of epithelial cells at low and moderate concentrations, while suppressing it at high concentrations.

Two studies^{24,31} stated that patients with aphthous stomatitis benefit from the use of SLS-free toothpaste, as this can decrease the number of ulcerations, the duration of the ulcerations and the intensity of the pain caused by the ulcerations. Mucosal desquamation caused by SLS seems to decrease when triclosan is

added.²⁶ According to one study,²² the oral mucosa of premenopausal women was significantly more sensitive to SLS than the oral mucosa of postmenopausal women since the mucosa of the latter is more keratinized. Desquamation was observed in this study only in toothpastes with SLS. From two articles,^{7,21} it appears that SLS in toothpastes causes inflammatory reactions of the anterior dorsal tongue.

In two further articles,^{19,25} SLS did not seem to have any side effects as it did not stimulate the formation of aphthous stomatitis. Toothpastes free of SLS had no significant effect on recurrent mouth ulcers compared to that with SLS.¹⁹

Discussion

This scoping review mapped the studies reporting on the possible side effects of SLS in the mouth or in the body when incorporated in toothpastes. A scoping review was performed as they are ideal tools to study the body of evidence from the literature on a given topic especially for examining emerging evidence when unclear results are present and where more specific questions need to be addressed through a more precise systematic review.

Based on the selected articles, clinical data has shown that SLS can cause ulcerations and irritation. SLS may damage the barrier function of the oral mucosa through denaturing the glycoproteins of the mucin layer further yielding to a higher vulnerability of the gums and oral mucosa to irritants such as exogenous antigens. Mucin is the main organic component of mucus, which is the viscoelastic material that covers all mucous membrane surfaces and plays an essential role in protecting these membranes.³²⁻³⁵

SLS increases the incidence of recurrent aphthous ulcers due to disintegration of the mucin layer, denaturation of proteins in the epithelial cells, dissolution of structural lipids of the cells and penetration of SLS into deeper layers of the mucous membrane where functions of the tissue can be affected.^{19,28,32,34}

Research shows that toothpastes without SLS are as effective as toothpastes with SLS, at least when gingival bleeding and plaque scores are considered.²⁶ The purpose of adding a detergent is its cleansing effect. Also, according to the selected studies, small amounts of SLS remain in the mouth, and this is quickly washed away by saliva. One may wonder what the need is to add SLS to toothpastes.

SLS is known as an irritant and is therefore widely used in patch tests. Possible alternatives to SLS were suggested as CAPB, stearyl ethoxylate or alkyoamidobetaines.^{22,32} However, more research is needed to verify this statement. Since children tend to swallow more amounts of toothpaste compared to adults, certain amounts of SLS may enter the gastrointestinal system. Thus, it is worth performing further research on SLS and its effect on the gastrointestinal system.

More research is needed to gain better insight into the effects of SLS in toothpaste on the oral and general health. Ideally, randomized clinical trials would be the best way to evaluate the effect of SLS in toothpastes. Recurrent aphthous stomatitis, recurrent aphthous ulcers, and cancer related sore spots are the most common ulcerative diseases of the oral mucosa. It is anticipated that the effect of SLS on such diseases is not based on a direct causal etiological reaction but more be-

cause of an effect on the vanishing of the mucous protective layer of the oral mucosa. This would then make the mucosa of the individuals suffering from recurrent aphthous lesions even more permeable to irritants from food as well as for the possible irritant effect of SLS itself.³⁶ The incidence of recurrent aphthous lesions is often associated with irregular appearance, requiring a clinical study on the effect of SLS not only on a large sample but also with a long evaluation period.

In conclusion, from this scoping review, it could be concluded that when incorporated in toothpastes, sodium lauryl sulfate may present possible side effects such as mucosal desquamation, irritation, inflammation of oral mucosa or the dorsal part of the tongue, ulcerations, and toxic reactions in the oral cavity, providing that a stronger body of evidence is needed.

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