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NATURAL REMEDIES TARGET DIFFERENT THERAPEUTIC PATHWAYS IN ORAL MUCOSITIS INDUCED BY CANCER CHEMO OR RADIOTHERAPY

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ABSTRACT: Oral mucositis (OM) is an inflammatory condition affecting oral mucosa. The etiology of this type of inflammation is associated with exposure to radiotherapy or chemotherapeutic drugs. Herbal drugs have been used to induce healing of different types of gastrointestinal ulcers. The role of medicinal plant in cancer therapy-induced oral mucositis has been investigated extensively. Preclinical studies refer to healing activity of some medicinal plants such as Chamomile, royal jelly, *Calendula officinalis* and *salvadora perisca* in oral mucositis induced by either chemotherapy or radiotherapy. Some herbal drugs are proved to have potential efficacy in decreasing both incidence and severity of oral mucositis in clinical studies. The molecular targets modulated by herbal drugs are various including scavenging reactive oxygen species (ROS), inhibition of inflammatory cascade, prevention of keratinocyte apoptosis and induction of some growth factors. This review, illustrates the common herbal drugs that have been used for oral mucositis management focusing on different therapeutic pathways that are implicated in this pharmacologic activity.

INTRODUCTION: Oral mucositis is an inflammatory condition that affects the mucosa of the oral cavity. The etiology of this type of inflammation is associated with exposure to radiotherapy or chemotherapeutic drugs^{1, 2}. Patients under chemotherapeutic protocols that induced bone marrow-suppression are at high risk of oral mucositis. Approximately 60-100% of those patients may encounter oral mucositis, patients who need radiotherapy directed at the oral, submandibular and pharyngeal area such as those who have squamous cell carcinoma in the head and neck region commonly have oral mucositis³.

Combination of radiotherapy and chemotherapy is associated with a risk of around 100%². Oral mucositis is a painful condition that significantly affects patients' quality of life⁴. The severe case is associated with ulcerated mucosa and secondary infection which may lead to life-threatening sepsis.

Herbal drugs have been used to induce healing of different types of gastrointestinal ulcers such as gastric ulcer, aphthous stomatitis, ulcerative colitis and oral mucositis⁵⁻⁸. The role of medicinal plants in cancer therapy-induced oral mucositis has been investigated extensively. Preclinical studies refer to healing activity of some medicinal plants like Chamomile, royal jelly, *Calendula officinalis* and *Salvadora perisca* in oral mucositis⁹⁻¹². Recently, some of medicinal plants products are formulated in various dosage forms. These preparations have been proved to be effective in the prevention of oral mucositis in patients under chemo or radiotherapy¹³⁻¹⁵.

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This review illustrates the common herbal drugs that have been used for oral mucositis management focusing on different therapeutic pathways that are targeted by these medicinal plants.

Pathophysiology of Oral Mucositis: Oral mucositis induced by antineoplastic via direct epithelial cell injury starting with DNA strand breaks concurrently with production of reactive oxygen species (ROS) ¹⁶ especially in early stage of oral mucositis which results in consumption of large quantities of antioxidants molecules including glutathione ¹⁷. Degraded DNA strand and ROS activate nuclear factor- κ B (NF- κ B) ¹⁸. It an important factor that up-regulates expression of pro-inflammatory cytokines such as tumor necrosis factor α (TNF- α), Interleukin 1 β (IL-1 β), and Interleukin 6 (IL-6). Those cytokines amplify tissue damage ^{19, 20}. Tissue damage is deteriorated with activation of matrix metalloproteinase as a result of activated pro-inflammatory molecules ^{21, 22}.

All these processes led to the formation of ulcers in the mucosa. The healing phase of oral mucositis initiated by signaling pathways starting in an endothelial cell with a specific growth factor that controls the renewal of epithelial cell proliferation and differentiation. Keratinocyte growth factor (KGF) is one of the key molecules that regulate communication between endothelial and epithelial cells. It is associated with triggering epithelial cells growth and differentiation ²³.

Evidence for Efficacy of Traditional Medicine in Oral Mucositis:

Chamomile: There are two types of chamomile, german chamomile (*Chamomilla recutita*) and roman chamomile (*Chamaemelum nobile*). The main active constituents of Chamomile flowers are terpenoids and flavonoids ²⁴.

Pavesi and his colleagues ⁹ reported that topical preparation of chamomile decreases the incidence and severity of oral mucositis induced by 5-fluorouracil in the hamster. It has been reported that Chamomile ointment decreases the severity of oral mucositis by decreasing pro-inflammatory cytokine ²⁵. These results were further evaluated in clinical studies. One of these studied use cammomile extract as an infusion. Cammomile infusion decreased the incidence and severity of

mucositis when used as adjuvant therapy with cryotherapy in a patient under 5-fluorouracil and leucovorin protocols. Moreover, the toxic profile of Cammomile infusion showed a wide margin of safety ¹³.

Results of another randomized, controlled, phase II clinical trial pointed out that cammomile mouthwash (containing 1% *C. recutita* extract) can be associated with the reduction in incidence, intensity, and duration of mucositis in patients undergoing allogeneic hematopoietic stem cell transplantation HSCT ²⁶.

Calendula officinalis: *Calendula officinalis* is a member of the Asteraceae family. Extract of *C. officinalis* flowers contains active constituents that have a different pharmacological activity such as bactericidal, antiseptic, anti-inflammatory, and antioxidant ¹¹. Topical *Calendula officinalis* extract formulated as gel accelerated the healing of oral mucositis induced by 5-fluorouracil (5-FU) in hamsters ¹¹. Clinically, *C. officinalis* mouthwash ameliorated the severity of radiotherapy-induced oral mucositis in patients with head and neck cancer ¹⁴.

Salvadora persica: Miswak (*Salvadora persica* L.) is the most widely used chewing stick for oral hygiene in middle-eastern and eastern African cultures, which is prepared from the roots or stems of *Salvadora persica* L. (*S. persica*) ²⁷. *S. persica* accelerates healing of ulceration induced by ethanol, indomethacin and cold restraint stress in rats ²⁸. Recently, *Salvadora persica* aqueous extract was found to decrease the incidence of oral mucositis induced by 5-fluorouracil in rats. The mechanism underlying this effect may be multi-factorial including preservation of oral hygiene as well as increased level of KGF in mucosa tissues ¹².

Different herbal remedies that showed promising results in preventing or accelerate healing of oral mucositis are summarized in **Table 1**.

Herbal Remedies Combination: Traditional Japanese herbal medicine prescribes herbal remedies that contain different medicinal plants such as Daiokanzoto (TJ-84) and Hangeshashinto. The composition of Hangeshashinto is illustrated in **Table 2**.

The herbal combination Daiokanzoto has an anti-inflammatory and immunomodulatory effect suggesting possible benefits in treating oral mucositis. It has been reported that Daiokanzoto exerts some activity in decreasing apoptosis in gingival cells (SA3 cell line) exposed to 5-fluorouracil through inhibition of ROS release from mitochondria³⁷. Similarly, Using Hangeshashinto

(TJ-14) enables patients under chemo-radiotherapy to complete their treatment course and preserve their nutritional status during treatment periods³⁸. Results from the random placebo-controlled study revealed that Hangeshashinto is effective in treating mucositis in colorectal cancer patients under different chemotherapeutic protocols³⁹.

TABLE 1: EVIDENCE OF DIFFERENT HERBAL REMEDIES EFFICACY IN PREVENTING OR RETARDING ORAL MUCOSITIS INDUCED BY CHEMOTHERAPY

Plant name	Oral Mucositis Model	Results	Proposed Mechanism
Korean red ginseng	Radiation-induced oral mucositis in a rat	Decrease the severity of oral mucositis in rats	Inhibition of keratinocyte apoptosis ²⁹
<i>Hippophae rhamnoides</i> extract	Oral mucositis induced in rats with methotrexate	Decrease incidence and severity of oral mucositis in rats	Antioxidant and anti-inflammatory ³⁰
Topical olive leaf extract	Oral mucositis induced by 5-fluorouracil in the golden hamster	Improve healing of oral mucositis in the golden hamster	Antioxidant ⁸
<i>Zizyphus jujuba</i> extract	Oral mucositis induced by 5-fluorouracil in the golden hamster	Improve healing of oral mucositis in the golden hamster	Antioxidant and anti-inflammatory ³¹
Hydroalcoholic extract of <i>Carum carvi</i> L.	Oral mucositis induced by 5-fluorouracil in the golden hamster	Improve healing of oral mucositis in the golden hamster	Antibacterial ³²
<i>Salvadora persica</i> extract	Oral mucositis induced by 5-fluorouracil in rats	Decrease incidence and severity of oral mucositis in rats	Oral hygiene Induction of KGF ¹²
<i>Clandula officinalis</i>	Oral mucositis induced by 5-fluorouracil in hamster	Improve healing of oral mucositis in the golden hamster	Antioxidant ^{11, 14}
Royal jelly (3%, 10%, and 30%) ointments	Oral mucositis induced by 5-fluorouracil in hamster	Improve healing of oral mucositis in the golden hamster	Antioxidant ^{10, 33}
Honey	Clinical studies on radiochemotherapy-induced mucositis in head and neck cancer patients.	Significant reduction in grade 4 mucositis	Anti-inflammatory ^{34, 35}

TABLE 2: COMPOSITION OF HANGESHASHINTO³⁶

Name of Herb	Dry Weight (g) per day
<i>Pinelliae ternatae</i> Rhizoma	5
<i>Scutellariae baicalensis</i> Radix	2.5
<i>Glycyrrhizae uralensis</i> Radix	2.5
<i>Zizyphi jujubae</i> Fructus	2.5
<i>Gin seng</i> Radix	2.5
<i>Coptidis</i> Rhizoma	1
<i>Zingiberis officinalis</i> Recens Rhizoma	2.5

Molecular Targets Modulated by Traditional Medicine:

Antioxidant: Chemotherapy and radiotherapy are associated with the release of ROS which plays a pivotal role in initiating a cascade that ends in tissue damage. Moreover, ROS have direct toxicity to mucosal cells⁴⁰⁻⁴². Hence, scavenging ROS could limit the progress of mucositis cascade and ameliorates tissue damage. In normal cells, ROS level is managed by the balance between ROS and

antioxidant enzyme, e.g., glutathione peroxidase, glutathione reductase, SOD and catalase. Scavenging ROS and activation of an antioxidant enzyme is considered as the main pharmacologic targets modulated by many herbal drugs. This may attribute to many antioxidant substances such as polyphenol and flavonoid. For example, *Calendula officinalis* decreases the intensity of radiotherapy-induced oral mucositis¹⁴. The effects of this medicinal plant are mostly related to its antioxidant compositions such as polyphenols, carotenoids and triterpenes. The main flavonoid in *C. officinalis* is quercetin this compound has potent antioxidant activities^{14, 43}.

In the same manner, *Hippophae rhamnoides* exerts a prophylactic effect against methotrexate-induced oral mucositis³⁰. The *H. rhamnoides* leaf extract has potent antioxidant activity due to the bioactive

phenolic constituents, such as quercetin-3-O-galactoside, quercetin-3-O-glucoside, kaempferol and isorhamnetin⁴⁴. Similarly, the antioxidant polyphenol particularly oleuropein and hydroxytyrosol found in topical olive leaf extract is responsible for its healing activity of oral mucositis induced by 5-fluorouracil^{8,11}.

Zizyphus jujuba is an herb that is widely distributed in Europe and South-eastern Asia. The main active constituents in this herb are cyclopeptide alkaloids, flavonoids, sterols, jujuboside A, jujuboside B, lauric acid, and triterpenoid and saponins⁴⁵. Topical and systemic forms of *Z. jujuba* hydro-alcoholic extract are associated with the reduced intensity of oral mucositis of golden hamster undergoing 5-FU consumption mainly due to antioxidant effect as measured as the low level of MDA and increased activity of SOD on mucosa³¹.

Anti-inflammatory: As discussed in the pathophysiology section above, induction of pro-inflammatory cytokines such as (TNF- α), Interleukin 1 β (IL-1 β), and Interleukin 6 (IL-6) play an important role in the amplification of tissue injury through activation NF- κ B and matrix metalloproteinase^{19, 20}. Targeting these pro-inflammatory cytokines may be an important part of the pharmacological activity of some medicinal herbs such as chamomile and *Hippophae rhamnoides*. Chamomile, Royal jelly, and *Hippophae rhamnoides* reduce the tissue levels of IL-1 β and TNF- α ^{25, 30, 33}. Other herbal drugs block inflammatory cascade and decrease the formation of prostaglandin. Honey has an anti-inflammatory effect; it inhibits prostaglandin level in both plasma and mucosa tissue³⁵.

The Japanese herbal combination hangeshashinto enable patients to complete chemo-radiation therapeutic course partially due to its anti-inflammatory activity⁴⁶. Kono and his colleagues explained that hangeshashinto reduce PGE2 production in human oral keratinocyte. They suggested that this anti-inflammatory action is due to the presence of an active ingredient that inhibits inflammation such as [6] - shogaol, [6] - gingerol, wogonin, baicalein, baicalin, and berberine⁴⁷.

Oral Hygiene: Maintaining Oral hygiene is very important in patients receiving chemotherapy⁴⁸. Those patients are of high risk of secondary

infection which may be life-threatening as those patients are already neutropenic due to chemotherapy⁴⁹. *Salvadora persica* Linn. protect a variety of microorganism⁵⁰⁻⁵³. The reported antiseptic effect of *S. persica* is attributed to its phytoconstituents such as vitamin C, salvadorine, salvadouria, alkaloids, trimethylamine, cyanogenic glycosides, tannins, saponins, and salts mostly as chlorides⁵⁴⁻⁵⁷.

Moreover, it has been reported that *S. persica* aqueous extract contains potential antimicrobial anionic compound such as Cl, SO₄ and SCN²⁷. The use of *S. persica* was associated decrease in incidence and severity of oral mucositis induced by 5- fluorouracil in rats. This may impart due to maintaining oral hygiene and induction of growth factor expression such as KGF¹². Similarly, a topical form of *Carum carvi* Linn. (caraway) is associated with the reduced intensity of oral mucositis due to impart appropriate antibacterial activity of its terpinene contents³².

Inhibition of Keratinocyte Apoptosis: Radio therapy-induced apoptosis is one of the important molecular events in oral mucositis. Radiation induces activation of caspase³. The activated caspase 3 cleaves the RNA-binding protein HuR and subsequently promotes the expression of the pro-apoptotic factor Bax⁵⁸. Inflammatory molecules that released during the progress of mucositis often share in apoptosis induction in mucositis⁵⁹. Korean red ginseng inhibit caspase induced opotosis in the oral mucosa of irradiated rats²⁹, *Artemisia asiatica* is an herbal drug that have an anti-apoptotic effect. *Artemisia asiatica* reduced the expression of cytochrome c, cleaved caspase-3 and nuclear factor-kappa B (NF- κ B) induced by cisplatin. Moreover, it induces the expression of Antiapoptotic gene Bcl-2²⁹.

Analgesic Effect: Some medical herbs have an analgesic effect. This effect is potentially important in oral ulcerative mucositis which is very painful. The processed ginger extract contains two analgesic compounds namely [6] - gingerol and [6] - shogaol. These constituents inhibit voltage-activated Na⁺ currents. Moreover, they inhibit the stimulant-induced release of substance P and action potential generation in cultured rat sensory neurons⁶⁰.

Induction of Growth Factor: Healing process is initiated by signaling pathways that target proliferation and differentiation of epithelial cells. Various types of growth factor are incorporated in different interaction to stimulate epithelial cell growth⁶¹. The most promising growth factor that regulates growth and proliferation of epithelial cell is the fibroblast growth factors (FGFs). Keratinocyte growth factor (KGF) is the most potent growth factors that induce epithelial growth and proliferation. Palifermin, the generic name of KGF, is the first compound approved by the FDA to reduce oral mucositis in patients receiving HSCT⁶². Limited studies investigated the role of herbal remedies in the induction of growth factor. *S. persica* enhances expression of KGF in mucosal tissues of 5- fluorouracil treated rats¹². On the other hand, Watanabe and his colleagues³³ reported that royal jelly couldn't increase the release of KGF from HPdLFs cells.

CONCLUSION: Herbal remedies are effective as an alternative therapy for oral mucositis. Data collected from both animal and clinical studies suggest herbal remedies as adjuvant therapy for oral mucositis induced by chemo or radiotherapy. Herbal drugs modulate different therapeutic pathways such as scavenging ROS, inhibiting inflammatory processes, inhibiting keratinocyte apoptosis and maintaining oral hygiene in addition to the analgesic effect of some product. I think that multicenter randomized studies are needed to clarify the efficacy and safety of different herbal products as a therapeutic option for oral mucositis.

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