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REVIEW

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To pack or not to pack: the current status of periodontal dressings

Rahul Kathariya, Hansa Jain, Tanya Jadhav

Department of Periodontics and Oral Implantology, Dr. D.Y. Patil Dental College and Hospital, Dr. D.Y. Patil Vidyapeeth (Deemed University), Pune - India

ABSTRACT

Surgical wound dressings have been employed over several centuries for the purpose of protection of surgical sites, to prevent postoperative infection and to accelerate healing. Periodontal dressings, also known as periodontal packs, provide similar benefits when applied after periodontal surgical procedures. They can broadly be categorized as eugenol-based dressings and noneugenol dressings. Over the years, many modifications have been made to the composition of such dressings to improve their physical and therapeutic properties. Controversies surrounding the rationale for their use, advantages and disadvantages of the most commonly employed periodontal dressings and their current status in clinical practice are described in this comprehensive review. From the evidence-based literature presented here, we have also attempted to answer the question of whether there is a universal need for the application of periodontal dressings.

Key words: Eugenol pack, Noneugenol pack, Periodontal dressing, Periodontal pack

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INTRODUCTION

Wound healing is a complex and dynamic process of restoring cellular structures and tissue layers. This biologic process can be broadly divided into 3 distinct phases – i.e., inflammatory, proliferative and remodeling. Within these 3 phases, a complex and coordinated series of events takes place. The culmination of wound healing results in the restoration of normal structure and formation of the injured tissue.

Louis Pasteur stated, "The germ is nothing. It is the terrain in which it is found that is everything." Factors that influence wound healing must be addressed in a holistic fashion, looking, as Pasteur suggested, at the terrain in which the wound is found (1). One may thus infer that the environment in which a wound heals plays a critical role. This favorable environment can be, in part, created by a surgical dressing. A surgical dressing allows for uninterrupted healing to occur and also contributes to the protection of the surgical area and prevention of wound damage and infection. The first surgical dressing was patented by E. P. Lesher in 1953 (US Patent 2632443) (2).

Similarly, a surgical dressing is also utilized after periodontal surgical procedures. These dressings are applied around the necks of the teeth and adjacent tissue to cover and protect the surgical wound after periodontal surgery (3). They are applied to serve as a bandage over the surgical site with the objective of holding the flap in place; protecting newly formed tissue; minimizing postoperative pain, infection and hemorrhage; protecting the surgical site from trauma during eating and drinking and finally, supporting mobile teeth during the healing process. Zentler in 1918 (4) first reported the use of a periodontal dressing in the form of iodoform gauze. This marked the beginning of a trend toward using periodontal dressings after surgery. A. W. Ward in 1923 (5) invented the Wondrpak, using the word *pack* in this context for the first time.

TYPES OF PERIODONTAL DRESSINGS

Periodontal dressings are generally grouped into 3 categories: (i) those containing zinc oxide and eugenol, (ii) those containing zinc oxide without eugenol and (iii) those containing neither zinc oxide nor eugenol. The name, type and composition of each of the commercially available dressings have been tabulated in Table I.

Eugenol dressings

The Wondrpak was the first periodontal dressing introduced containing eugenol (5). It was a 2-component system comprising a powder with zinc oxide, powdered pine resin, talc and asbestos and a liquid containing

TABLE I - NAME, TYPE AND COMPOSITION OF EACH COMMERCIALLY AVAILABLE DRESSING

Sr. No.	Name	Type	Composition
1	Ward's Wondrpak	Eugenol dressing	Powder – zinc oxide, powdered pine resin, talc & asbestos Liquid – isopropyl alcohol 10%, clove oil, pine resin, pine oil, peanut oil, camphor & coloring materials
2	Kirkland formula	Eugenol dressing	Zinc oxide, resin, zinc acetate, eugenol, tannic acid and olive oil.
3	Coe-Pak	Noneugenol dressing	Two pastes First paste – zinc oxide, added oils, gums & lorothidol Second paste – unsaturated fatty acids & chlorothymol
4	Cross Pack	Noneugenol dressing	Colophony powder, zinc oxide, tannic acid bentonite & powdered neomycin sulphate
5	Peripac	Noneugenol dressing	Calcium sulphate, zinc oxide, zinc sulphate, acrylic type of resin & glycol solvent
6	Septopack	Noneugenol dressing	Amyl acetate, dibutyl phthalate, butyl polymetacrylate, zinc oxide, zinc sulphate
7	PerioCare	Noneugenol dressing	Two pastes First paste – paste of metal oxides in vegetable oil Second paste – gel of rosin suspended in fatty acids
8	Perio Putty	Noneugenol dressing	Methylparabens, propylparabens, benzocaine
9	Periogenix™	Noneugenol dressing	Perfluorodecalin, purified water, glycerin, hydrogenated phosphatidylcholine, cetearyl alcohol, polysorbate 60, tocopheryl acetate, benzyl alcohol, methylparaben, propylparaben, & oxygen
10	Cyanoacrylate dressings	Other	n-Butyl cyanoacrylate
11	Light cure dressings	Other	Silicon dioxide crystalline – quartz, hydrophobic amorphous fumed silica, urethane dimethacrylate resin
12	Collagen dressing	Other	Type I collagen derived from bovine tendon mixed with cancellous granules
13	Stomato adhesive dressing	Other	Gelatin, pectin, sodium carboxymethylcellulose and polysio polysiobutylene

isopropyl alcohol, clove oil, pine resin, pine oil, peanut oil, camphor and coloring materials (6). A modified form of a eugenol dressing was introduced by Kirkland, called the Kirkland formula. It consisted of zinc oxide, resin, zinc acetate, eugenol, tannic acid and olive oil. The composition of such eugenol dressings has evolved over the years; potentially caustic products such as asbestos and tannic acid have been eliminated from the dressings due to their possible detrimental systemic effects. Asbestos was found to have the potential to cause asbestosis, lung cancer and mesothelioma (7). Tannic acid was found to cause potential liver damage, if absorbed systemically (8). On the other hand, a few components were added to improve the properties – e.g., the addition of zinc acetate as an accelerator to increase the working time (9, 10).

Zinc oxide and eugenol dressings are supplied as a liquid and powder or paste. These are mixed together on a waxed paper pad using a wooden tongue depressor or spatula. The powder or paste is gradually incorporated into the liquid until it reaches a dough-like consistency. The dressing may be used immediately or wrapped in aluminum foil and refrigerated for use for up to 1 week (9).

Role of eugenol

Eugenol-based dressings were formerly popular, especially following gingivectomy (11), due to their property of obtunding pain and rendering sites less sensitive. Waerhaug and Löe in 1957 (12) commented that zinc oxide–eugenol dressings seemed to prevent or retard bacterial growth based on their antiseptic properties. However, eugenol was found to irritate oral mucosal tissues, induce allergic reactions and cause tissue necrosis, particularly of bone, which led to delay in healing (13). Furthermore, it presents difficulties in manipulation and has a rough surface after setting. Histological evidence has also shown that eugenol-containing dressings produce greater tissue destruction, with more inflammatory cell infiltration and connective tissue response (14, 15). Eugenol has proven to be cytotoxic at higher concentrations and has an adverse effect on fibroblasts and osteoblast-like cells (16).

TABLE II - COMPOSITION AND INGREDIENTS OF COE-PAK AND THEIR FUNCTIONS

Pastes	Composition	Specific ingredients	Function
Base paste	Oils	Oils of clove	Principal ingrediant
	Rosin	Petrolatum	Plasticity, viscocity
			To reduce brittleness, Speeds the reaction
	Fatty acids	Fatty acids	Lubrication
	Chlorothymol	6-chlorothymol	Bacteriostatic agent
	Alcohol	ethyl alcohol	Luting agent, viscocity, micromechanical adhesion
	Metal salts	Zinc acetate	Strength, decrease setting time, accelerator
	Cellulose	Cellulose asters Sodium carboxy methyl cellulose	Manipulation
Catalyst (accelerator) paste	Oxides	Zinc oxide Magnesium oxide	Principal ingredient, accelerators, modifiers, fillers
	Oils	Vegetable oils	Plasticizer, masks the action of eugenol as irritant
	Chlorothymol	Chlorothymol Chlorodimethyl phenyl	Bacteriostatic agent
	Lorothidol	Lorothidol	Fungicyde
	Silica	Ethyl Silicate/ sodium silicate	Binder, filler
	Resins	Syntheticn resins	Plasticity
	Coumarin	Coumadin	Anticoagulant

Data from (2, 3, 6, 9-11, 13, 17, 18).

All of these reasons lead to the development of noneugenol dressings in the late 1950s.

Noneugenol dressings

Noneugenol dressings are currently the most widely used periodontal dressings. Commercially available noneugenol dressings include Coe-Pak, Cross Pack, Peripac, Septopack, PerioCare, Perio Putty and Periogenix.

Coe-Pak™

Coe-Pak is the most widely used noneugenol intraoral dressing in the United States, and is manufactured by Coe Laboratories (Alsip, IL, USA). It consists of 2 pastes (Tab. II): the base paste which contains zinc oxide with added oils and gums, and lorothidol which is a fungicide related to hexachlorophene. The catalyst paste contains coconut fatty acids thickened with colophony resin or rosin and chlorothymol as an antibacterial agent. Equal lengths of material are placed on a waxed paper pad and mixed using a wooden tongue depressor until a thick consistency and uniform color is reached. The setting time can be altered by adding a few drops of warm water during mixing or by immersing the pack into a bowl of warm water just after mixing. Once the paste loses its tackiness, it can be handled and molded using gloves lubricated with water or petroleum. The pack is then formed into pencil-sized rolls that are then mechanically interlocked in the facial and lingual interproximal areas (Fig. 1) (19). The Coe-Pak is available in regular set and hard and fast set formulations, based on its setting time and consistency, and it is supplied commercially both in manual mix and automix varieties.

Cross Pack

Cross Pack was formerly the powder part of a zinc oxide–eugenol dressing in use in the late 1940s (W.G. Cross, personal communication, 1974). It consists of colophony powder, zinc oxide, tannic acid, bentonite and powdered neomycin sulphate. Cross Pack is added as a filler to Coe-Pak to give more body to the material. Zinc oxide alone can be used instead of Cross Pack if desired (11).

Peripac®

Peripac (Dentsply, Konstanz, Germany) is a paste containing calcium sulphate, zinc sulphate, zinc oxide, polymethyl methacrylate, dimethoxy tetraethylene glycol, ascorbic acid, flavor and iron oxide pigment. It reacts on exposure to air or moisture through loss of the glycol, dimethoxy tetraethylene glycol. Peripac is indicated as a dressing following gingivectomies and papillectomies, deep curettage, reattachment surgery and gingival repositioning. It can also be used in treatment of necrotic gingivitis and ulcers; protection of nonspecific lesions or sutured margins, fixation of desensitizing medicaments to cervical areas and temporary rebasing of immediate dentures in periodontal surgery (11).

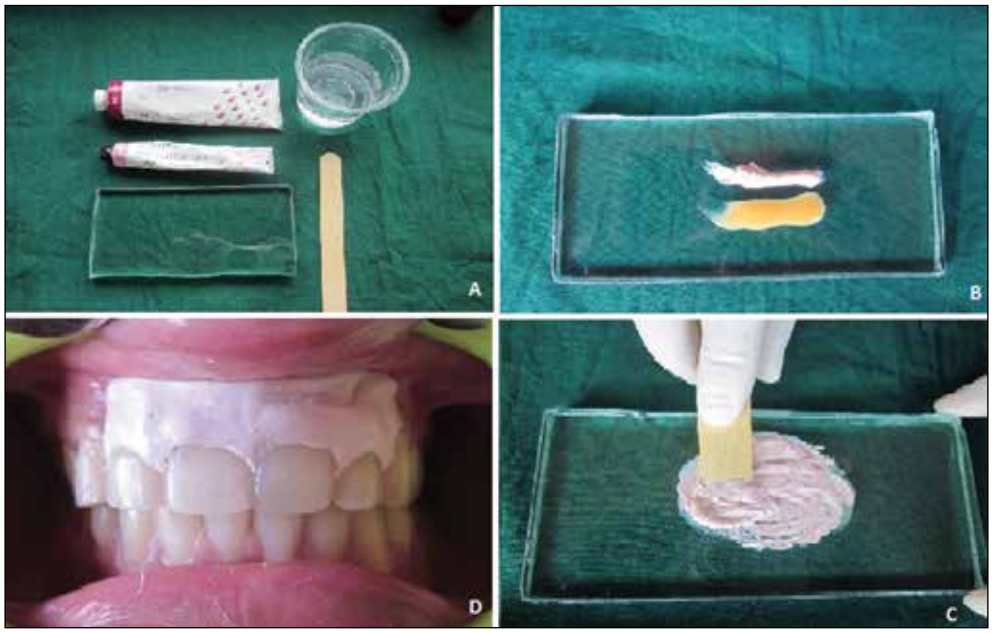

Fig. 1 - ***A)*** *Materials required for Coe-Pak periodontal dressing: base and catalyst paste, glass slab, wooden spatula and saline water.* ***B)*** *Equal streaks of base and catalyst paste.* ***C)*** *Mixing of base and catalyst pastes with a wooden spatula to get uniform color.* ***D)*** *Placement and adaption of dressing material.*

Septo-Pack

Septo-Pack (Septodont, Saint Maur-des-Fosses, France) contains amyl acetate, dibutyl phthalate, butyl polymetacrylate, zinc oxide, zinc sulphate and excipient. It is a self-hardening plastic paste containing fibers in its mass. It can also be combined, as a neutral medium, with some medicines so that they can be kept in place easily on the gingiva or tooth or at the alveolar ridge level. Neither Peripac nor Septopack contains any specific antibacterial agent (11).

PerioCare

PerioCare (Pulpdent Corp., Watertown, MA, USA) is a highly elastic periodontal dressing and sets resiliently hard. It comes in a 2-paste system: 1 contains a paste of metal oxides in vegetable oil, and the other contains a gel of rosin suspended in fatty acids. Equal amounts of the pastes are dispensed, mixed and applied.

Perio Putty

Perio Putty (Cadco Dental Products Inc., Los Angeles, CA USA) is another noneugenol dressing containing methylparabens and propylparabens for their effective fungicidal properties and benzocaine as a topical anesthetic (10).

Periogenix™

Periogenix™ is a noneugenol dressing manufactured by OroScience (New Line Medical Inc., Lafayette, LA, USA). It contains perfluorodecalin, purified water, glycerin, hydrogenated phosphatidylcholine, cetearyl alcohol, polysorbate 60, tocopheryl acetate, benzyl alcohol, methylparaben, propylparaben and oxygen. It has been said that this dressing accelerates healing of postoperative surgical wounds. It was also observed that wounds treated with Periogenix™ demonstrated an up-regulation of vascular endothelial growth factors, collagens I and III, and matrix metalloproteinase levels. Periogenix™ allows for the exchange of oxygen and carbon dioxide into and out of injured tissues. This property has been shown to promote wound healing by stimulating several processes, including neovascularization, collagen production, epithelization, phagocytosis neutrophil-mediated oxidative microbial killing, and degradation of necrotic wound tissue (20).

The main advantages of noneugenol dressings are minimal irritation of the mucous membrane, pleasant odor, neutral taste, ease of manipulation, pliability which facilitates easy removal from undercut areas and elimination of the objectionable taste of eugenol. Although they possess neither the analgesic nor antibacterial properties of eugenol dressings, they are less irritating and form a closely adapted adhesive barrier to saliva and oral bacteria (21).

Dressings containing neither zinc oxide nor eugenol

The third group of periodontal dressings consists of cyanoacrylate dressing, light cure dressing, collagen dressing and mucoadhesive/stomahesive dressing.

Cyanoacrylate

The cyanoacrylate alkyls were obtained for the first time in 1949 by A. E. Ardis (22). It was in 1959 that Coover

et al (23) synthesized tissue adhesive materials and suggested their possible use as surgical adhesives. Their chemical formula is H_2C = C(CN)COOR, where R- can be substituted for any alkyl group ranging from methyl to decyl. The earlier methyls were found to be histotoxic and thus were discontinued in clinical practice. Only n-butyl cyanoacrylate was found to be biocompatible and therefore was suggested to be used in surgical procedures (e.g., Histoacryl®; B. Braun Biosurgicals, Germany and PeriAcryl®; Glustitch Inc, Delta, Canada). As a dressing it has been evaluated clinically and histologically following procedures such as gingivectomy, mucoperiosteal flaps, excisional biopsies, free mucosal grafts, frenectomies and for oral mucosal ulcers (24). It is useful because it provides rapid hemostasis in the presence of moisture due to polymerization. It accelerates initial healing by acting as a protective barrier maintaining precise positioning of a flap or free gingival graft and also possesses antimicrobial properties (10).

Light cure dressings

Light cure dressings (e.g., Bucrylate; Ethicon Inc., Somerville, NJ, USA) is a novel concept for the protection of periodontal surgical sites. It is a single-component, light-activated dressing material supplied in a syringe for direct placement. It is cured in increments with a visible light curing unit and retains its elasticity on setting. It is tasteless and has a tinted pink translucent color, and is thus usually preferred in the anterior segment (25).

Collagen dressings

Collagen dressings (e.g., Colla products from Zimmer Dental, Carlsbad, CA, USA) are biological dressings which create a physiologic interface between the wound and the environment and encourage healing by deposition and organization of the fibers in granulation tissues formed freshly in the wound bed. The advantages over other dressings include ease of application, nonimmunogenic, nonpyrogenic, hypoallergenic properties. Moreover, an inherent property of native collagen is the ability to promote hemostasis by facilitating aggregation of platelets and subsequently, the coagulation cascade. Additionally, the structure of absorbable collagen provides a 3-dimensional matrix for strengthening the blood clot. Commercially available collagen dressings have three forms: tape (CollaTape; Zimmer Dental, Carlsbad, CA, USA), cote (CollaCote, Zimmer Dental, Carlsbad, CA, USA) and plug (CollaPlug; Zimmer Dental, Carlsbad, CA, USA). Tape is used for localized ridge defects, socket grafting, Schneiderian membrane tears, subantral augmentations and protection of soft tissue donor sites. Cote is used in procedures like soft tissue recontouring, sinus graft containment, guided bone regeneration and sinus membrane perforations, whereas, a plug is used as a dressing for biopsy sites (26).

Some surgeons reported the use of mucoadhesive/stomahesive dressing (CovaTec, Middlesex, UK), whenever mucosal coverage is required for a short period of time. It is an adhesive, nonsensitizing wound dressing which was patented by Peter L. Steer and Howard Mathew in 1982 (US Patent 3,339,546). It is a multilayered dressing including a layer of curative and absorbent material which makes contact with the wounds, a layer of deodorizing material and an outer layer which secures the bandage to the tissues. The contents include gelatin, pectin, sodium carboxymethylcellulose and polyisobutylene. The longevity of the dressing is minimal (dissolves in 8-24 hours) (see Hall (19) p. 208). However, some surgeons find this short time adequate for protecting the donor and recipient sites of a soft tissue graft or for gingivoplasty procedures (19, 27).

Modifications

Many attempts have been made to enhance the properties of dressings, as described in the following section.

Dressing and chlorhexidine

Chlorhexidine is an established antibacterial agent with long-term activity in the oral cavity owing to its substantivity and slow-release properties. In 1989, most commercial periodontal dressings claiming to have initially good antimicrobial activity, lost this activity shortly after application. Thus the addition of chlorhexidine to dressings to improve their properties was proposed.

As early as 1975, Addy and Douglas (27) tested the antibacterial properties of a chlorhexidine-containing gel in vitro and in vivo, and found that methacrylate gel is a good medium for carrying chlorhexidine to the wound area and releasing it slowly.

Chlorhexidine salts were also incorporated into the dressings in the form of a powder mixed along with the dressing material. Plüss et al in 1975 incorporated 15-20 mg of chlorhexidine dihydrochloride in a periodontal dressing (Peripac) and documented a significant reduction in the amount of plaque formation (28). They attributed this to the direct contact of the powder with the teeth. In another similar study, Othman et al found that surgical dressings containing antimicrobial agents, having high retention and and slow release properties are advantages (29, 30).

Other chlorhexidine formulations such as mouth rinses and varnishes were also used adjunctively with periodontal dressings. Numerous studies in which chlorhexidine mouth rinses have been prescribed have reported significantly less plaque accumulation and less sulcular bleeding and exudate (31, 32). In a study by Zyskind et al, chlorhexidine varnish was applied prior to the application of a periodontal dressing (33). Significantly less plaque was found on teeth pre-coated with the slow-release varnish.

Numerous reports have published data regarding the benefits of addition of various chlorhexidine formulations to periodontal dressings (28-32, 34). Clinical trials supporting the use of periodontal dressing are tabulated in Table III. In contrast, there were trials which demonstrated no additional plaque inhibitory effects (32) and refuted the use of periodontal dressing are tabulated in Table IV. A review of the literature seems to suggest that the addition of chlorhexidine is a valuable asset in postsurgical care as it inhibits plaque growth. However, since the use of chlorhexidine mouth rinses is preferred by patients, the practice of direct incorporation of chlorhexidine powder in the dressing seems to have waned. Additionally, mouth rinses have a rinsing and washing off effect against the bacteria from the potential infection site and can reach more surfaces compared with any hard or semirigid materials.

Dressing and antibacterial agents

To enhance healing and prevent infections, the addition of antibiotics to dressings has been evaluated (Tab. V). The earliest reports outlining the use of tetracycline are by Fraleigh (55) and of zinc bacitracin, by Baer et al (56). In 1972, Grant et al discussed this subject and stated that the possible advantages of the use of bactericidal and bacteriostatic drugs in periodontal dressings had not been fully investigated and pointed out the possibility of sensitization and allergy, and the potential development of candidiasis with the use of these drugs (57).

Though the addition of these agents is beneficial, there are a few authors who claim that their addition may be harmful. Heaney et al (50) suggested the removal of the dressing within 7 days of application, as antimicrobial

TABLE III - CLINICAL TRIALS SUPPORTING THE USE OF PERIODONTAL DRESSINGS

Clinical trials: author (ref.)	Reason
Ariaudo and Tyrell (35)	Protection of wound from mechanical trauma, stability of the surgical site during healing process
Prichard (36)	Patient comfort during healing, good adaptation to underlying gingival and bony tissue, prevention of postoperative hemorrhage or infection, decreasing tooth hypersensitivity, protecting the clot from forces applied during speaking or chewing, preventing gingival detachment from the root surface
Wikesjo et al (37)	Prevention of flap displacement in apically repositioned flaps, additional support in free gingival grafting procedures
Sigusch et al (38)	Periodontal wound dressing has a positive effect on clinical long-term results

TABLE IV - CLINICAL TRIALS NOT IN FAVOR OF USE OF PERIODONTAL DRESSINGS

Clinical trials: author (ref.)	Reason
Loe and Silness (39)	Dressing has little effect
Stahl et al (40)	Dressing accumulates plaque
Harpenau (41)	No difference in clinical parameters
Greensmith (42)	No differences in healing
Kidd and Wade (43)	Greater pain experience Plaque accumulation Subsequent microbial invasion Nonpack areas showed better wound healing Lesser pain scores
Jones and Cassingham (44)	Irritates healthy tissue increases chances of infection
Allen and Caffesse (45)	No difference in PD, CAL and gingival inflammation
Checchi and Trombelli (46)	No statistical differences in pain scores and number of analgesics consumed between the pack and nonpack groups. Postoperative pain with dressing
Bose et al (2013) (47)	Pronounced swelling increases plaque accumulation Increases inflammation and GCF Difficult in eating

CAL = Clinical attachment level; GCF = Gingival crevicular fluid; PD = Pocket Depth.

TABLE V - STUDIES ASSESSING ANTIBACTERIAL PROPERTIES OF PERIODONTAL DRESSING AGAINST MICROORGANISMS FOUND AT THE SURGICAL SITES (48)

1	Coppes et al (49) in comparison of microorganism types between eugenol and noneugenol dressings, revealed the frequency of *Bacteroides melaninogenica* to be higher under eugenol-free dressings.
2	Heaney et al (50) took a bacterial sample from the areas under two periodontal dressings. They revealed that the most frequent microorganisms under Coe-Pak were gram-negative rods, although the incidence of yeasts was higher under ZOE dressing.
3	Plüss (28) showed that significantly less plaque formed under periodontal packs with chlorhexidine powder than under control packs.
4	In evaluation of healing process, O'Neil (11) revealed that tested periodontal dressings (Coe-Pak, Cross-Pak, Peripac, Septo-Pak, ZOE) had no antibacterial properties, and ZOE had minimal antifungal properties.
5	In some *in vitro* studies (11, 18, 50, 51, 52), antibacterial properties of periodontal dressings against bacterial plaque have been reported to be inconsistent.
6	Haugen and Gjermo (6) revealed that the tested periodontal dressings (Wondrpak, Coe-Pak and Peripac) had antibacterial effects on salivary microorganisms.
7	The effect of chlorhexidine supplementation on periodontal dressing was assessed by Othman et al (29). They showed that the durability of chlorhexidine efficacy in periodontal dressing depends on its concentration.
8	Sustained-release varnish of chlorhexidine as an inhibitor of plaque accumulation under periodontal dressings was evaluated by Zyskind et al (33). The application of chlorhexidine varnish under tested dressings caused less plaque accumulation compared with the control group.
9	Volozhin et al (52) showed that the frequency of aggressive microorganisms in periodontal pockets of patients with generalized chronic periodontitis reduced when the periodontal dressing consisting of collagen and *Lactobacillus casei* 37 cell suspension was used.
10	Ikeda T et al (53) and Woodcock (54) in their studies revealed that biguanides like polyhexamethylene biguanide (PHMB) have better physical properties than chlorhexidine. PHMB has extensive antibacterial activity against a wide range of gram-positive bacteria and fungi and causes destabilization of the bacterial cell membrane.

agents used in conjunction with dressings may allow for selective inhibition of microorganisms and bring about variations in complex oral microbiota. Two possible problems may occur: emergence of resistant organisms and opportunistic infections. In the study cited, organisms resistant to certain antibacterials predominated under the dressings used, but led to no adverse effect. Romanow (58) found that clinical signs of candidiasis occurred when using tetracycline in dressings and that bacitracin was found to enhance the growth of yeasts. In 1983, Breloff and Caffesse (59) tested the effect of Achromycin applied underneath a dressing and showed that topical Achromycin had no beneficial effect on healing.

In light of the current trend toward overuse of antibiotics, we emphasize that the antibiotics should be used only after the antibiogram (except in some acute cases such as acute necrotizing ulcerative gingivitis (ANUG)) and should not be used with all periodontal dressings for every periodontal treatment.

Other medicaments and dressings

The addition of noneugenol phenol derivatives such as chlorothymol and oil of bergamot was described by Molnar (60) and by Schach (61), respectively. To improve postoperative healing, Saad and Swenson (62) and Swann et al (63) added steroids and Dilantin to dressings. Such agents had been previously reported to increase the rate of healing in skin wounds of rats and humans, but neither agent showed any advantage in these periodontal studies.

In 2011, a study conducted by Srakaew et al (64) evaluated the possibility of metal complex formation between sodium-phosphorylated chitosan and zinc oxide. The polymer-metal complex formation was investigated in terms of thermal degradation. Indications of cytotoxicity, evaluated by a direct contact test with primary human gingival fibroblast cells, revealed that sodium-phosphorylated chitosan was biocompatible and reduced the cytotoxicity of zinc oxide by complexation, making sodium-phosphorylated chitosan/zinc oxide complexes potentially biocompatible. The authors concluded that sodium-phosphorylated chitosan could be used as a reaction rate-modifying agent (reacting speed controlling agent) in periodontal dressings.

Substitutes for dressings

In 1975, the modification of a methacrylic gel for use as a periodontal dressing was attempted, and the results suggested that the modified methacrylic gel fulfilled the requirements of a periodontal dressing. However, further research was proposed for the use of this gel as a dressing (28).

In 1990, a study was carried out with the aim of evaluating the healing of the gingival grafts covered with Solcoseryl dental adhesive paste (containing protein-free calf blood extract and lauromacrogol) in comparison with the grafts covered with Peripac. The results indicated that the adhesive paste can be used as a periodontal dressing (26). Thus, the use of adhesive pastes was also considered as a substitute for conventional dressings (26, 35).

Benefits of a dressing

The benefits of a dressing can be divided into 2 subgroups: physical benefits and therapeutic benefits.

Physical effects

With the advent of flap repositioning, advocated by Ariaudo and Tyrell (35), it was established that the periodontal dressing could be used as a stent. It was Prichard (65) who stated that a dressing was to be used to prevent postoperative hemorrhage and to protect the wound area from contact with food, concluding that a dressing "has no other virtue." Later, Manson (66) said that a dressing is applied to protect a healing wound from saliva and trauma, thus producing comfort and enhancing healing. Ramfjord (67) stated that closed curettage causes a periodontal trauma – i.e., it often results in a relatively wide dehiscence of the buccal and lingual papillae. He advocated that after completion of the treatment, the soft tissue should be brought into close contact with the tooth again, either by interproximal sutures or by a firm dressing for better postoperative results. Wikesjo et al (37) also described elevated sensibility of healing during the first few hours and days, especially in the process of fibrin attachment to the root surface. They stated that a dressing protected the coagulum from forces exerted during talking and chewing and prevented its detachment from the root surface. Subsequently, Plagman (68) recommended the covering of the wound area for 3-4 days with a periodontal pack in addition to suturing, because the dressing prevented food debris from impacting in the interdental spaces. He assumed that the coagulum had to be stabilized so that movements of the healing epithelium were prevented and an untroubled attachment to hard tissues was guaranteed.

Recently a study was carried out by Genovesi et al (69) to test the hypothesis that the placement of a periodontal dressing would be able to prevent detachment of coagulum, inducing proper healing and improving periodontal parameters, after nonsurgical periodontal therapy. Their results evidently suggested that the use of a periodontal dressing improved the periodontal parameters even after scaling and root planing. This was attributed to clot stabilization and prevention of bacterial colonization during wound healing.

To summarize, we can say that the list of physical benefits of a periodontal dressing includes protection of the postsurgical wound from postoperative trauma, saliva, and food debris and stabilization of the blood clot. Secondly, it limits the entry of bacteria and other microorganisms which may cause infection and other complications. Furthermore, it has been suggested that it acts as a splint for loose teeth and to immobilize newly positioned grafts and flaps. We find it imperative here to mention that only the light cure dressings have this ability, and stabilization of loose teeth is not a principal goal of a dressing. The splinting of loose teeth should be done by composite- or glass fiber–reinforced composite materials prior to the nonsurgical or surgical periodontal treatment. Although none of the current studies confirm the hypothesis that splinting itself causes better healing after the periodontal treatment, they seem to suggest that the stabilization of the teeth brings better results because of the stable environment around the blood clot and dispersion of the occlusal forces to the surrounding teeth. Finally, a dressing may control postoperative discomfort in the early stages of healing.

Therapeutic effects

Ward (5) advocated the use of a periodontal dressing to bypass pain, infection and root sensitivity and to prevent formation of caseous deposits on the root surface. He felt a dressing would also act to provide temporary support after gingivectomy. Orban (70) used a zinc oxide eugenol dressing and observed that better healing occurred after gingivectomy if the dressing was changed every 2 to 4 days for 10 to 14 days. However, he also noted that if the dressing was left in place in excess of 12 days, delayed healing occurred. Box and Ham (71) described the use of a zinc oxide eugenol dressing after performing a chemical curettage for the treatment of necrotizing ulcerative gingivitis. This significantly improved the clinical parameters. Bernier and Kaplan (72) reported that the use of a dressing facilitates the healing process. They indicated that the dressing's function as a surface barrier provided the primary benefit, while the constituents of the dressing appeared to be of secondary importance. Blanqui (73) stated that the purpose of a periodontal dressing was to control postoperative discomfort, allowing tissue healing under aseptic conditions, preventing reestablishment of a periodontal pocket and desensitizing denuded cementum.

Loe and Silness (39) reported that exposed tissue will heal irrespective of the application of a protective dressing. However, they felt that the dressing provided an environment more favorable for optimum healing. The use of isobutyl cyanoacrylates, self curing and light curing packs led Bhaskar et al (74) to consider instant hemostasis as one of its main advantages. Greensmith and Wade (42) using a split mouth surgical technique, evaluated healing

after reverse bevel flap procedures with or without a dressing. They concluded that the application of a dressing led to statistically slightly better results, as indicated by a shallower pocket and lower gingival index in spite of a slight increase in inflammation. In the same year Asboe-Jörgensen et al (30) discussed the use of dressings after periodontal surgery in terms of improved patient comfort. Linsky et al (75) said that if a wound was provided with a dressing and was thereby "closed," the inflammatory response produced was significantly lesser than that in open wounds. Eaglstein (17) mentioned that "wounds of the skin that had been provided with a dressing healed significantly faster."

Regarding the improvement in clinical periodontal parameters, clinical probing depth and probing attachment level using a dressing following nonsurgical periodontal therapy have also been documented (17, 69).

A literature review thus suggests that the therapeutic effects of a dressing include control of bleeding or hemostasis, improvement in clinical periodontal parameters, desensitization of denuded root surface and prevention of reestablishment of periodontal pockets.

Retention of packs

Much has been said and thought about the retention of the periodontal dressings. In the 1950s, numerous splints and stents were used to stabilize the periodontal dressings. The materials used were acrylic resin, advocated by McKenzie (76) and later by Munns (77). In 1953, Waerhaug and Anerud (78) described interproximal use of spiral saws and lengthwise cotton thread. Later, Hirschfeld and Wasserman (79) listed a whole battery of techniques, including the use of wire, floss, acrylic, adhesive tin foil and copper bands. In 1952, Castenfelt (80) mentioned the use of cotton tapes with interdental sutures. Cowan (81) advocated the inclusion of wiring to increase the retention. Subsequently, in 1970, Smith (82) reported preliminary trials with polyacrylate dressing materials. Addy and Douglas (27) also attempted to incorporate some degree of adhesion into their chlorhexidine-carrying material, by employing polyacrylic acid. Two other research groups, Asboe-Jörgensen et al (30) and Plüss et al (28), decided to employ auxiliary methods of retention for their chlorhexidine-containing dressings. That entailed the use of a custom-made vinyl splint sealed at the periphery by a thin ring of Coe-Pak to provide additional retention. From the data mentioned above, it can be observed that much research has been done to enhance the retentiveness of dressing, but the ideal dressing is the one which does not require any retention.

Retention of dressing over palatal wounds has always gained extra attention due to the postoperative morbidity of the open palatal wounds. Through the years, researchers have been trying to search for an explicit way to cover this region and impede the complications that may follow. In 1992, Ferguson (83) described a technique which utilized a light-cured periodontal dressing – i.e., Barricaid in conjunction with the surgical exposure of palatally displaced maxillary canines. The procedure was very quick and simple to perform.

It was noted that a composite intraoral dressing remained secure for days if incorporated with various appliances in the anterior palate (e.g., quad-helix coil for maxillary expansion, orthodontic brackets or a retainer wire). This observation led them to consider 3 techniques for purposeful retention of a composite dressing over a freshly closed alveopalatal wound. The first technique roped in the use of circumdental wire buttons – the Kazanjian button, named after the researcher who reported it (84). However, Kazanjian credits Wilson as the originator. The second technique included the use of interdental wires in which circumdental wire was wrapped like a chord from an anterior tooth to a posterior tooth on the opposite side of the palate, across the wound. The third technique included use of bonded brackets, in which brackets were placed on the teeth preoperatively or intraoperatively with light-cured composite cement on an acid-etched enamel surface, and the retention was further enhanced by using arch wires. The use of a composite dressing was the fourth technique in this area, in which a Coe-Pak composite dressing was placed over the alveolar and/or palatal wound, incorporating the wire or brackets.

In 2003, cotton gauze with α-cyanoacrylate was used for alveolopalatal wound dressing after alveolar bone grafting in alveolar cleft patients. It helped reduce mechanical injuries, tension from wound dehiscence and adhesion of food remnants. T-shaped cotton gauze was placed on the gingivoperiosteal flaps and was impregnated with cyanoacrylate. The authors reported that this technique was a convenient and dependable one (85). In the same year, Lisa Harpenau elaborated on the additional hemostasis which may be required for palatal donor sites. She recommended the use of a surgical absorbable hemostat such as Surgicel, CollaCote or Avitene, applied over the wound bed over which the periodontal dressing or palatal stent can be placed.

Physical properties of various dressings

Two chemically cured (Coe-Pak and PerioCare) and 1 photocured dressing (Barricaid) were examined by von Fraunhofer and Argyropoulos (86). All materials absorbed water, both Coe-Pak and PerioCare acted in a similar manner at 23˚C, but PerioCare absorbed far more water at 37˚C. For Barricaid, it was shown that increased light exposure had little effect on its water sorption or solubility. It was also shown that there was no difference in the solubility of each material when immersed at 23˚C and 37˚C. When immersed in 0.9% KCl solution, Barricaid had no

effect on solution conductivity or pH, however Coe-Pak and PerioCare were found to increase conductivity slightly and increase pH notably. The adhesion of different dressings was also tested. Adhesion of Coe-Pak to a single tooth at 1 hour was about 7 kg, but this decreased to about 6.5 kg at 24 hours and to 5 kg at 7 days. The adhesion of PerioCare was 2 kg at 1 hour and 8.5 kg at 24 hours, but it decreased to 7.5 kg at 7 days. The adhesion of Barricaid was about 5 kg at 1 hour, which decreased to 3.5 kg at 24 hours and 1.5 kg at 7 days. The mechanism of adhesion of Barricaid appeared to involve mechanical locking, which differs from that of Coe-Pak and PerioCare.

Another study showed that if teeth were etched and a bonding agent was applied to the etched enamel surface, the chemomechanical lock between tooth surface and Barricaid dressing gave an immediate adhesion value of 43.94 MPa, which decreased to 37.17 MPa at 7 days. The immediate adhesion value without etching and bonding was 34.23 MPa which decreased to 19.32 MPa at 7 days. Soaking decreased adhesion to enamel, but the effect was markedly less when the enamel was pretreated by etching and priming.

Watts and Combe (87) compared Coe-Pak, Peripac and Peripac Improved (containing polyacrylic acid and butyl phthalate as plasticizer; for their effects on composite filling material and on a glass ionomer cement. Placement of adhesive foil between a dressing and teeth with composite restorations, to protect them from deterioration, was recommended. When the viscosity of Coe-Pak, Peripac and Peripac Improved was tested, none of the dressings exhibited ideal flow properties during manipulation and adaptation, and no dressing exhibited an adequately well-defined set.

BIOLOGICAL PROPERTIES

Effects on wound healing

Eugenol-free dressings were developed to offset the irritant and toxic properties of liquid eugenol. Numerous reports have outlined the adverse tissue effects and intensity of inflammatory reaction with the use of a eugenol-based dressing (12, 13). At the same time, in vitro studies have revealed that eugenol-based dressings may cause less growth inhibition of permanent cells and primary human leukocytes than some noneugenol products (14, 15).

The literature is also replete with comparative studies of eugenol-based and noneugenol dressings. It has been established that dressings such as PPC and WondrPak produce greater tissue destruction, with more inflammatory cell infiltration and connective tissue response, involving a much wider reaction area in the adjacent tissues (14, 15). Comparative evaluation of different noneugenol dressings has shown conflicting results. Coe-Pak, in a few studies, showed a severe tissue reaction as compared with Peripac and PerioPutty (88), which elicited the least inflammatory response, whereas in others, Coe-Pak was also seen to cause least damage (89).

However, the results of implantation tests are not uniform. Some tests report that eugenol-based dressings caused no tissue reactions (90), others reported a severe tissue reaction (88) and a few reported no difference between eugenol-based and noneugenol dressings (91). Thus, differentiating the irritant behavior based on eugenol content does not seem to be justified.

Cell culture studies using cultured human gingival fibroblasts seem to reflect more consistent results regarding the relative biologic effects of these dressings. Eugenol-based dressings were found to inhibit fibroblast proliferation to a greater extent than noneugenol dressings (92). Comparison of noneugenol dressings revealed that Vocopac, Peripac and Barricaid did not inhibit growth of human primary gingival fibroblasts, while Coe-Pak reduced the proliferation of the fibroblasts (16). A few culture studies carried out with fibroblasts showed minor differences between eugenol and noneugenol products (93).

Also, light-cured periodontal dressings were not cytotoxic in cell cultures and different cell types (94). With the development of collagen-based dressings, products such as CollaCote had better clinical and histological effects on palatal wound healing than Coe-Pak (95). The various studies describing the cytotoxicity of periodontal dressing have been enumerated in Table VI.

The literature thus seems to suggest that in comparison, noneugenol dressings are more biocompatible than their eugenol counterparts. Furthermore, dressings falling in other categories including light cure dressing, Barricaid and collagen-based dressing CollaCote are better than the conventional noneugenol based dressings.

Therapeutic effects of antimicrobial agents in dressings

The antimicrobial properties of dressings is a perplexing issue and the literature provides mixed reviews regarding the topic (Tab. V). Eugenol-based dressings were found to have a bacteriostatic effect in vitro (102) and were also found to alter the plaque composition as a result of selective inhibition (49). A comparative evaluation of periodontal dressings revealed that the antimicrobial activity of Coe-Pak was greatest, while that of Peripac was the least (103); others comparing Coe-Pak, Cross Pack, Peripac, Septopack and a zinc oxide–eugenol dressing noted that none of the materials tested showed any marked degree of antibacterial activity (11).

Postoperative pain and dressing

One of the purposes of periodontal dressings is to aid in reducing postoperative discomfort. In earlier reports, measuring the degree of pain experienced by the patient

TABLE VI - STUDIES ASSESSING PERIODONTAL DRESSING CYTOTOXICITY (36)

1.	An in vitro cell culture technique suggested that the solubility of the leachable toxic substances in cell culture medium is an important factor responsible for various behaviors of dressings (6)
2.	Haugen et al (96, 97) introduced Wondrpak as the most irritating product, followed by Coe-Pak and Peripac.
3.	Haugen et al (98): Under laboratory conditions, fresh samples of Coe-Pak and Wondrpak cause more hemolysis than other products, and the cytotoxicity of Coe-Pak increases with time.
4.	Nezwek et al (88) and Wennberg et al (89) in their in vitro studies, investigated tissue reactions to some periodontal dressings. They reported that the greatest inflammatory reaction was caused by Wondrpak. Also, Wennberg et al showed that when the contact period increased to 3 days, Peri-pac showed a more severe tissue reaction than Wondrpak.
5.	Smeekens et al (99) in an animal study, suggested that the products that contain eugenol trigger greater inflammatory reactions, although this increase was not significant in other studies.
6.	By using scanning electron microscopy and L-929 cell media, the cytotoxicity of some periodontal dressings was assessed. They showed that all of the materials had an insignificant toxic effect on L-929 cell lines, and Sne-Pack and Coe-Pak dressings were smoother than ZOE (100).
7.	By using cell culture medium, Barricaid was introduced as a cyto-compatible dressing, where human gingival fibroblasts, 3T3 mouse fibroblasts and human osteoblast-like cells (HOBI) were used (16).
8.	Baer and Wertheimer (100), Haugen and Mjör (98) and Saito et al (101) in their studies showed that periodontal dressings can cause greater inflammatory infiltration on the bone and the inflammatory reaction is greater when the dressing is directly placed on the bone compared with the time when it is placed on the periosteum.

was done based on the consumption of analgesic tablets. Such studies reported that the experience of pain was significantly more frequent after the use of Peripac than Coe-Pak and Wondrpak, based on higher tablet consumption in the Peripac group. Also, when sensitivity was observed, it was seen that the highest proportion of sensitive teeth was found after the use of Coe-Pak, and the lowest with Peripac (43). Pain measurements using visual analogue scale (VAS) studies have reported that pain scores with Coe-Pak were higher than with Wondrpak after a gingivectomy procedure (104). The same authors, in another study, compared pain experience after gingivectomy when using a local anesthetic agent. They reported that pain was masked when using a eugenol-based periodontal dressing, thus proving that eugenol dressings cause less pain than noneugenol ones (105).

PERIODONTAL DRESSINGS FOR ALL?

Having discussed at length the biologic and therapeutic benefits of a periodontal dressing, the question of whether we need to use a dressing for all surgical procedures remains open. The fact that complete healing can take place even without a dressing, provided the surgical area is kept clean, and that there is no difference in healing between dressed and nondressed wounds, lends support to the theory that not all surgical areas need to be "packed" (39). Other factors such as the presence of inflammation seemed to influence the rate of wound healing to a larger extent than the use of a dressing (40). A number of clinical trials have proposed that the use of a dressing accumulates plaque-causing inflammation (51, 106), irritates the healing tissues, produces transient bacteremia during postoperative dressing change (107) and causes more pain and swelling but less sensitivity and difficulty in eating (42, 44). Despite these drawbacks, it appears that healing is slightly more rapid in the dressed segments.

The use of periodontal dressings from the patients' preference and comfort point of view has also been elaborated. Conflicting reports exist in the literature, as these factors are based on patient responses and thus are not objectively evaluated, because of the subjective criteria usually employed. The use of chlorhexidine mouth rinse instead of a dressing has been found to reduce postoperative plaque accumulation and surgical inflammation (106) and is considered to be roughly equivalent to professional plaque control in postsurgical healing, thus providing a viable alternative regime for plaque control (108). Moreover, many patients experienced discomfort when a periodontal dressing was used and preferred to use a mouth rinse. Conversely, some patients exhibited a psychological feeling of protection and well-being when a periodontal dressing was put in place (38, 46).

The answer to this controversy, though still open to debate, is probably that the choice of use of a periodontal dressing is a matter of individual preference and the judgment of the operator. It is, however, prudent to use a dressing for stabilization of free gingival grafts and protection of donor site, retention of an apically positioned flap, protection of the denuded bone from further injury, protection of the graft site in periodontal regeneration and

to facilitate retention of drugs delivered locally in the subgingival sites (10).

CONCLUSION

There appears to be no consensus regarding the absolute indication for the use of periodontal dressings after a surgical procedure. However, the literature does elaborate on the benefits of application of a dressing postsurgically. Moreover, no periodontal dressing material has been shown to exhibit all of the ideal properties – both physical and biologic. We believe that further research to improve biomaterial properties may lead to a more universal applicability. As for now, periodontal dressings for all? – maybe, not yet!

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Address for correspondence:
Dr. Rahul Kathariya
Department of Periodontics and Oral Implantology
Dr. D.Y. Patil Dental College and Hospital
Dr. D.Y. Patil Vidyapeeth (Deemed University)
Pune 411018, India
rkathariya@gmail.com

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