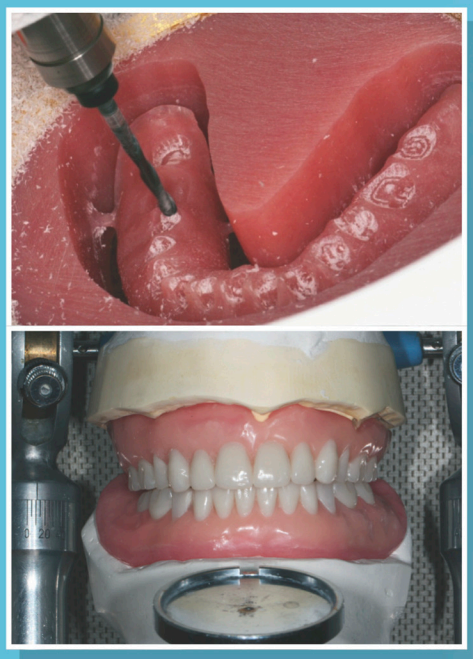
Journal of Prosthodontics

on Complete and Removable Dentures



Edited by

Jonathan P. Wiens
Jennifer Wiens Priebe
Donald A. Curtis

ACP AMERICAN COLLEGE OF PROSTHODONTISTS
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JOURNAL OF PROSTHODONTICS ON COMPLETE AND REMOVABLE DENTURES

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Edited by

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CONTENTS

PREFACE

Textbooks on removable complete dentures have historically included an emphasis on technical procedures and materials sciences as they apply to the rehabilitation of the edentulous patient. However, in this compilation of 30 articles from the *Journal of Prosthodontics*, we have also selected articles that provide insight to the functional, psychosocial, nutritional, and comorbid factors that influence our ability to improve outcomes for the edentulous patient. This is relevant, as the total number of patients in the United States needing dentures has been increasing and because the edentulous state is interconnected to a patient's general well being.

This textbook started with the review of over 2,000 *Journal of Prosthodontics* articles related to removable complete dentures. The authors established a ranking that resulted in the 30 most impactful articles.* We divided the 30 articles into five thematic parts: Part I; Edentulism and Comorbidities, Part II; Oral Health, Biofilms, and Denture Stomatitis, Part III; Treatment Innovations, Part IV; Functional Parameters and Assessment, and Part V; Esthetic Considerations. Of the 30 articles selected, the article by Felton, Cooper, Duqum, et al on "Evidence-based guidelines for the care and maintenance of complete dentures" is featured on the book cover.

We encourage you to review this textbook with the idea of advancing your understanding of removable complete dentures. In addition to the above-selected articles, we suggest readers consider searching additional valuable literature on removable complete dentures that is available in the *Journal* online. Valuable information can be found by searching for removable complete dentures and keywords such as education, parameters of care, materials testing, occlusion, treatment methods, patient acceptance, satisfaction, adaptability, maxillofacial prosthetics, laboratory, CAD/CAM digital dentures, anatomy, and preprosthetic surgery.

The editors appreciate the opportunity to provide this textbook on removable complete dentures and hope that you will find value in reading the selected articles.

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PART I

EDENTULISM AND COMORBIDITIES

1

EVIDENCE-BASED GUIDELINES FOR THE CARE AND MAINTENANCE OF COMPLETE DENTURES: A PUBLICATION OF THE AMERICAN COLLEGE OF PROSTHODONTISTS

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Keywords
Dentures; edentulism; biofilm; adhesives; denture cleansers; denture relining; denture rebasing; denture repair; denture wear; stomatitis.

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Reproduced under agreement with the American College of Prosthodontists. The American College of Prosthodontists led the development of these evidence-based denture care guidelines in collaboration with the Academy of General Dentistry, the American Dental Association Council on Scientific Affairs, the American Dental Hygienists' Association, the National Association of Dental Laboratories, and GlaxoSmithKline Consumer Healthcare.

Funding for the guidelines development project and for this special supplement was provided by GlaxoSmithKline Consumer Healthcare.

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Journal of Prosthodontics on Complete and Removable Dentures, First Edition. Edited by Jonathan P. Wiens, Jennifer Wiens Priebe, and Donald A. Curtis.

ABSTRACT

The current rates of edentulism have been estimated to be between 7% and 69% of the adult population internationally. In the United States, while the incidence of edentulism continues to decline, rapid population growth coupled with current economic conditions suggest that edentulism and conventional denture use will continue at current or higher numbers. Unfortunately, evidence-based guidelines for the care and maintenance of removable complete denture prostheses do not exist. In 2009, the American College of Prosthodontists (ACP) formed a task force to establish evidence-based guidelines for the care and maintenance of complete dentures. The task force comprised members of the ACP, the Academy of General Dentistry, American Dental Association (ADA) Council on Scientific Affairs, the American Dental Hygienists' Association, the National Association of Dental Laboratories, and representatives from GlaxoSmithKline Consumer Healthcare. The review process included the assessment of over 300 abstracts and selection of over 100 articles meeting inclusion criteria of this review. The task force reviewed synopses of the literature and formulated 15 evidence-based guidelines for denture care and maintenance. These guidelines were reviewed by clinical experts from the participating organizations and were published in February 2011 issue of *The Journal of the American Dental Association* for widespread distribution to the dental community. These guidelines reflect the views of the task force.

It is estimated that between 7% and 69% of adult populations internationally are affected with complete edentulism, which is defined as the loss of all permanent teeth.[1] Additionally, 26% of the U.S. population between the ages of 65 and 74 years are edentulous, and low income and education levels have the highest correlation with tooth loss.[2–4] While the incidence of complete edentulism in the United States continues to decline (approximately 6% between 1988 and 2000,[5] continued growth in the population strongly suggests that edentulism rates will remain constant or increase over the next few decades.[6] However, with the increasing need and expected demand for complete denture services, there are few published guidelines on the daily and long-term care and maintenance of complete denture prostheses.

METHODS

In 2009, the American College of Prosthodontists (ACP) formed a task force to develop contemporary, evidence-based guidelines for the care and maintenance of complete dentures. This task force comprised individuals representing the ACP, the Council on Scientific Affairs of the American Dental Association, the Academy of General Dentistry, the American Dental Hygienists' Association, the National Association of Dental Laboratories, and representatives from GlaxoSmithKline Consumer Healthcare.

A literature search was conducted by task force members using PubMed, EMBASE, known prosthodontic references and materials obtained from the U.S. Centers for Disease Control and Prevention. Search words and MEDLINE Medical Subject Headings for the search included the terms "complete dentures," "edentulism" and various combinations of those terms and the following: "biofilm," "adhesives," "cleansers," "cleaning," "relines," "rebases," "repairs," "nocturnal (or continuous) wear," "stomatitis," and "maintenance." Abstracts of the following types of articles were reviewed: Cochrane Reviews, systematic reviews, general literature reviews, meta-analyses, randomized controlled trials, prospective clinical trials, cross-sectional studies, retrospective cohort studies and any in vitro studies that introduced novel approaches to evaluation of the topic. Over 300 abstracts were reviewed, and set inclusion and exclusion criteria allowed the identification of 150 manuscripts, which were reviewed by members of the ACP. Inclusion criteria included:

- clinical trials involving more than 10 participants;
- clinical trials of more than 7 days' duration;
- crossover trials with or without a washout period.

The ACP task force members reviewed the abstracts and excluded from further assessment those studies that did not meet the inclusion criteria. The same task force members printed and reviewed full-text articles and collated all data from the manuscripts on manuscript review matrixes. The reviewers summarized data for discussion by the entire task force. Over 120 manuscripts were included in this review. After the reviewing task force members conducted a careful analysis of the manuscripts, they provided summaries to all task force members for review, and a meeting was held at the School of Dentistry, University of North Carolina Chapel Hill, in May 2010 to develop the guidelines. After the meeting and multiple conference calls, the document that follows was developed and agreed upon by the task force members.

This document provides the practicing clinician with the evidence-based guidelines for the care and maintenance of complete dentures. In the main portion of the document, the

guidelines are reported in bold type followed immediately by the evidentiary documentation. This document has been distributed to the communities of interest for review and input, and subsequently this document has been developed for distribution.

GUIDELINES FOR THE CARE AND MAINTENANCE OF DENTURES

Based on the best available evidence, the following are guidelines for the care and maintenance of dentures:

1. **Careful daily removal of the bacterial biofilm present in the oral cavity and on complete dentures is of paramount importance to minimize denture stomatitis and to help contribute to good oral and general health.**
2. **To reduce levels of biofilm and potentially harmful bacteria and fungi, patients who wear dentures should do the following:**
   (a) **Dentures should be cleaned daily by soaking and brushing with an effective, nonabrasive denture cleanser.**
   (b) **Denture cleansers should ONLY be used to clean dentures outside of the mouth.**
   (c) **Dentures should always be thoroughly rinsed after soaking and brushing with denture-cleansing solutions prior to reinsertion into the oral cavity. Always follow the product usage instructions.**
3. **Although the evidence is weak, dentures should be cleaned annually by a dentist or dental professional using ultrasonic cleansers to minimize biofilm accumulation over time.**
4. **Dentures should never be placed in boiling water.**
5. **Dentures should not be soaked in sodium hypochlorite bleach, or in products containing sodium hypochlorite, for periods that exceed 10 minutes. Placement of dentures in sodium hypochlorite solutions for periods longer than 10 minutes may damage dentures.**
6. **Dentures should be stored immersed in water after cleaning, when not replaced in the oral cavity, to avoid warping.**
7. **Denture adhesives, when properly used, can improve the retention and stability of dentures and help seal out the accumulation of food particles beneath the dentures, even in well-fitting dentures.**
8. **In a quality-of-life study[88] patient ratings showed that denture adhesives may improve the denture wearer's perceptions in retention, stability, and quality of life; however, there is insufficient evidence that adhesives improve masticatory function.**
9. **Evidence regarding the effects of denture adhesives on the oral tissues when used for periods longer than 6 months is lacking. Thus, extended use of denture adhesives should not be considered without periodic assessment of denture quality and health of the supporting tissues by a dentist, prosthodontist, or dental professional.**
10. **Improper use of zinc-containing denture adhesives may have adverse systemic effects. Therefore, as a precautionary measure, zinc-containing denture adhesives should be avoided.**
11. **Denture adhesive should only be used in sufficient quantities (three or four pea-sized dollops) on each denture to provide sufficient added retention and stability to the prostheses.**
12. **Denture adhesives should be completely removed from the prosthesis and the oral cavity on a daily basis.**
13. **If increasing amounts of adhesives are required to achieve the same level of denture retention, the patient should see a dentist or dental professional to evaluate the fit and stability of the dentures.**
14. **While existing studies provide conflicting results, it is not recommended that dentures should be worn continuously (24 hours per day) in an effort to reduce or minimize denture stomatitis.**
15. **Patients who wear dentures should be checked annually by the dentist, prosthodontist, or dental professional for maintenance of optimum denture fit and function, for evaluation for oral lesions and bone loss, and for assessment of oral health status.**

EDENTULISM: ITS RELATIONSHIP TO ORAL AND SYSTEMIC HEALTH

The oral health of the completely edentulous patient is a significant factor related to the quality of life, nutrition, social interactions and general systemic health of denture-wearing patients (for a review, see Felton[7]). While often not life-threatening, the presence of oral biofilm on complete dentures has been associated with denture stomatitis, as well as with more serious systemic conditions, especially in the dependent elderly. Published reports regarding the

relationship between oral health and systemic diseases in the edentulous, the partially edentulous and the dentate patient are increasing.

Oral bacteria have been implicated in bacterial endocarditis,[8–10] aspiration pneumonia,[11–20] chronic obstructive pulmonary disease,[21] generalized infections of the respiratory tract[22] and other systemic diseases.[23,24] Excellent reviews of the pathogenic potential of denture plaque have been published.[25,26]

A 2008 report by Ishikawa and colleagues[27] indicated that weekly professional cleaning of complete dentures (brushing, cleaning of dentures with denture brush, ultrasonic irrigation of denture with denture cleanser, swabbing of oral tissues with a sponge brush) significantly decreased multiple oral bacterial strains when compared with the daily chemical disinfection methods, and suggested this to be a viable strategy for reducing aspiration pneumonia in the dependent elderly. Clearly, evidence is mounting regarding the relationship between proper complete denture hygiene and overall systemic health.

DENTURE BIOFILMS

Dentures accumulate plaque, stain and calculus similar to the natural dentition. Failure to properly clean the accumulated biofilm from the dentures is associated with an increased incidence of localized denture stomatitis[28–30] in addition to the more serious systemic diseases noted earlier. Denture plaque is a complex aggregate of oral bacteria, fungi and other organisms; it is estimated to contain more than 10^{11} organisms per milligram (wet weight)[24] involving more than 30 different species.[31] While there is general consensus that the composition of denture plaque is similar to that of plaque in the dentate patient,[32] the biomass may vary between individuals and between sites in the oral cavity and sites on the dentures.

It has also been determined that dental biofilms accumulate more readily on rough denture surfaces than on smooth ones. In an in vitro study by Charman and colleagues,[33] denture acrylic resin samples were prepared to four different degrees of surface roughness, after which *Streptococcus oralis* was cultured on the samples. Specific areas of the acrylic resin were observed by using microscopy over eight incubation time points (inoculation period of 5 hours). Surface roughness varied from highly polished roughness average (Ra) value of 0.07 microns, to brushing with a mechanical brushing machine (Oral-B soft toothbrush) with baking soda (Ra value of 0.29 μm), to brushing with the same machine using silica toothpaste (Ra value of 0.38 μm), to sanding with silicon carbide paper (Ra value of 1.14 μm). The study demonstrated that there was increased coverage of the denture with *Streptococcus* bacteria as the surface roughness increased, and that heat-processed denture base acrylic was less likely to grow organisms than were cold-cured resin bases. The study may have a significant effect on the efficacy of denture cleaning, general denture hygiene and biofilm reformation of various cleaning regimens, and the results indicate that nonabrasive cleansers may offer a more appropriate regimen. Care should be taken not to scratch the surface of processed denture bases or acrylic prosthetic denture teeth; however, one needs to understand that the intaglio surface of the denture base, that surface in contact with the oral tissues, is never polished.

DENTURE STOMATITIS

Careful daily removal of the bacterial biofilm present in the oral cavity and on complete dentures is of paramount importance to minimize denture stomatitis and to help contribute to good oral and general health.

Denture stomatitis is a common occurrence in denture wearers, resulting in an area of erythema beneath the denture. Its etiology is multifactorial, and it may be associated with both local and systemic factors.[34] For a review on the topic, see Loewy.[35] As many as 67% of existing denture wearers are thought to have *Candida*-associated denture stomatitis.[36] The role of *Candida albicans* in the pathogenesis of denture stomatitis has been well investigated, and multiple strains of *Candida* have been found to populate the denture base, as well as the oral tissues.[30]

Recently, Campos et al[37] collected samples from both the oral tissues and corresponding regions on the intaglio surfaces of the dentures in patients who were healthy (had no inflammation), and from patients with denture stomatitis. They identified 82 bacterial species in healthy patients and those with denture stomatitis, including three types of *Candida* sp. However, 26 bacterial phylotopes were found only in the healthy denture wearers (with a strong representation of *Streptococcus* sp), while 32 phylotopes were exclusively found in those patients with denture stomatitis. The stomatitis group was represented by *Streptococcus* sp (23%), *Atopobium* sp (16%), and *Prevotella* sp (11%). *C. albicans* was identified as the primary fungal species in the stomatitis group, while there was a greater diversity of three *Candida* sp found in the healthy population (*C. albicans*, 22%; *Candida glabrata*, 54%; *Candida tropicalis*, 24%). The authors concluded that there appear to be distinct biofilms present in healthy subjects and in those with denture stomatitis. Denture stomatitis is a disease that is chronic and multifactorial, and it tends to compromise the edentulous patient's quality of life. Eradicating this disease requires treatment of both the oral tissues and the removable prostheses.

DENTURE CLEANING

To reduce levels of biofilm and potentially harmful bacteria and fungi, patients who wear dentures should do the following:

- **Dentures should be cleaned daily by soaking and brushing with an effective, nonabrasive denture cleanser.**
- **Denture cleansers should ONLY be used to clean dentures outside of the mouth.**
- **Dentures should always be thoroughly rinsed after soaking and brushing with denture-cleansing solutions prior to reinsertion into the oral cavity. Always follow the product usage instructions.**

Although the evidence is weak, dentures should be cleaned annually by a dentist or dental professional using ultrasonic cleansers to minimize biofilm accumulation over time.

Dentures should never be placed in boiling water.

Dentures should not be soaked in sodium hypochlorite bleach, or in products containing sodium hypochlorite, for periods that exceed 10 minutes. Placement of dentures in sodium hypochlorite solutions for periods longer than 10 minutes may damage dentures.

Dentures should be stored immersed in water after cleaning, when not replaced in the oral cavity, to avoid warping.

Because of the defined relationship of biofilm to stomatitis, dentists and healthcare providers must carefully instruct the edentulous patient in the proper methods for cleaning and maintaining dentures. An important unanswered question is what defines a "clean" removable denture.

The characteristics of an ideal denture cleanser should include the following

- It should, at a minimum, demonstrate antibiofilm activity to remove biofilm and stains and should be antibacterial and antifungal to minimize the level of biofilm and potentially harmful pathogens in the biofilm below clinically relevant levels; however, this acceptable level has yet to be defined.
- It should be nontoxic
- It should be compatible with denture materials, and should not modify (roughen) or degrade the surface of the acrylic resin denture base or prosthetic teeth.
- It should be short acting (≤8 hours).
- It should be easy to use for the patient or caregiver.
- It should have an acceptable (or no) taste.
- It should be cost effective.

Three literature reviews on denture cleansers were identified by the task force. Abelson's[38] review focused on the literature published between 1936 and 1983. The Abelson review described the nature of denture plaque and its role in oral disease. Additionally, Abelson reviewed the development of denture cleansers, their mechanism of cleansing and their efficacy. The Abelson review suggested that the use of abrasive pastes may be the most efficacious method of denture cleansing, that hypochlorite solutions were highly effective but potentially damaging to prostheses, and that new standards for evaluating denture cleansers were needed.

A second review by Nikawa et al[39] focused on the literature published between 1979 and 1995. This review covered more than 20 articles that evaluated the efficacy of denture cleansers and determined that the results obtained were highly dependent on the methods used to evaluate the selected cleansing methods. Nikawa et al,[39] like Abelson,[38] called for the development of a standardized method for evaluation of denture cleansers.

Third, a Cochrane Review on interventions for cleaning dentures was recently published by de Souza et al.[40] After careful comparison of the six clinical trials in this Cochrane Review[41–46] the authors suggested that there was no evidence that any denture-cleaning method is more beneficial than others for the health of the denture-bearing tissues or has a higher level of patient satisfaction or preference than that of others.

Brushing with denture creams and pastes: Three in vivo studies considered the efficacy of denture paste in biofilm removal. Dills et al[41] suggested that brushing with a denture paste was inferior to use of an effervescent cleaner or to use of the same cleaner followed by paste brushing. Panzeri et al[42] demonstrated that brushing with two types of pastes (one antibacterial and one with a fluorosurfactant) reduced the biofilm mass when compared with brushing with water; however, brushing with either paste had no impact on *Candida* sp colonization. Finally, Barnabé et al[43] compared brushing the dentures with coconut soap followed by soaking in sodium hypochlorite (NaOCl) (10 minutes) to brushing with soap and soaking in water. This cross-sectional study indicated that both treatments reduced the levels of denture stomatitis, but that neither treatment reduced the levels of *Candida* sp cultured from the prostheses. Thus, *Candida* sp appears to be resistant to mechanical debridement from the denture base. Other methods of denture cleansing appear superior to this method, and the abrasiveness of denture pastes is of concern.

Soaking and brushing with commercially available denture cleansers (effervescent tablets): Commercially available denture cleansers use various active agents—including hypochlorites, peroxides, enzymes, acids and oral mouth rinses—to remove biofilm from dentures. Each of these immersion cleansers has a different mode of action

and a different rate of efficacy for removal of adherent denture biofilms. While the denture-cleaning methods tested were capable of reducing the biomass present on dentures over the various time courses evaluated, none of the in vivo trials reviewed demonstrated that any of the methods used was bactericidal.[44–48] In vitro studies, however, have demonstrated that NaOCl was superior to all other types of commercially available denture cleansers.[49–55] In addition, the emergence of methicillin-resistant *Staphylococcus aureus* (MRSA), a major pathogen in the immunocompromised patient, has become a major issue in hospitalized patients, as MRSAs increase mortality rates significantly. An in vitro investigation by Lee and colleagues[57] indicated that NaOCl was capable of killing MRSA. Neither of the commercially available denture cleansers used in this trial was bactericidal against the pathogens tested, but both reduced the biomass levels.

Ultrasonic cleaning: Ultrasonic cleaning of dentures occurs frequently in both the dental office and the dental laboratory. The mode of action of ultrasonic devices is unique in that they produce ultrasonic sound waves (20 to 120 kHz), which create microscopic cavities (bubbles) that grow and implode. This implosion creates voids that result in localized areas of suction. Materials adhering to the denture are loosened and removed by this action. This action is commonly known as "cavitation." Two representative types of solutions that are commercially available for use in the ultrasonic cleaner are BioSonic Enzymatic (Coltène/Whaledent, Cuyahoga Falls, OH), which contains nonionic detergents, protease enzymes and 400 parts per million isopropyl alcohol, and Ultra-Kleen (Sterilex, Hunt Valley, MD), which requires the mixing of two solutions that results in the formation of an alkaline-peroxide cleanser. Interestingly, while ultrasonic cleaning demonstrated remarkably improved kill rates of bacteria, neither of these two solutions tested were completely bactericidal.[57,58] The literature review indicated that the use of other commercially available denture cleansers in conjunction with ultrasonic cleaning in the dental office has not been investigated.

Precautions associated with use of denture cleansers: In 2008 the U.S. Food and Drug Administration[59] (FDA) issued a requirement for manufacturers of denture cleansers to revise their labeling regarding contents, and to consider alternatives to the types of ingredients present in this class of products. This action was in response to 73 severe reactions, including at least one death, linked to denture cleansers. The specifically identified ingredient, persulfate, is known to cause allergic reactions. Persulfates are used in denture cleansers as part of the cleaning and bleaching process. Symptoms of the reaction to persulfates include

- irritation of the tissues;
- tissue damage;
- rash;
- hives;
- gum tenderness;
- breathing problems;
- low blood pressure.

The FDA noted that other reactions may be the result of misuse of the product by patients. The requirement specifically involves labeling revisions to ensure that denture wearers understand that these products are for use only when the dentures are outside the mouth. Symptoms related to misuse of the denture cleansers can include:

- damage to the esophagus;
- abdominal pain;
- burns;
- breathing problems;
- low blood pressure;
- seizures;
- bleaching of tissues;
- internal bleeding;
- vomiting.

Alternative denture cleansing methods: Currently, there are few techniques that sterilize complete dentures following intraoral use. Microwave irradiation of dentures immersed in sterile water at 650 Watts for three minutes sterilizes dentures without causing surface degradation of the prosthesis. However, the long-term effects of this technique have not been investigated.[60–63] Additionally, boiling of a denture base has been shown to deform the base, rendering it unusable. All other forms of denture cleansing appear to reduce the bacterial and fungal biofilm, but are disinfecting the prosthesis only. Of the immersion products available, NaOCl may be the most effective product available, but only when used properly (10-minute soaking). Soaking dentures for extended periods of time (i.e., overnight) in NaOCl may degrade the acrylic resin components, causing color changes (lightening), and therefore should be avoided. Additionally, once cleaned, dentures should remain immersed in water to prevent over drying of the base, with resultant warping of the prosthesis.

DENTURE CARE AND MANAGEMENT

Denture adhesives, when properly used, can improve the retention and stability of dentures and help seal out the accumulation of food particles beneath the dentures, even in well-fitting dentures.

In a quality-of-life study,[88] patient ratings showed that denture adhesives may improve the denture wearer's perceptions of retention, stability and quality of life;

however, there is insufficient evidence that adhesives improve masticatory function.

Evidence regarding the effects of denture adhesives on the oral tissues when used for periods longer than 6 months is lacking. Thus, extended use of denture adhesives should not be considered without periodic assessment of denture quality and health of the supporting tissues by a dentist, prosthodontist or dental professional.

Improper use of zinc-containing denture adhesives may have adverse systemic effects. Therefore, as a precautionary measure, zinc-containing denture adhesives should be avoided.

Denture adhesive should only be used in sufficient quantities (three or four pea-sized dollops) on each denture to provide sufficient added retention and stability to the prostheses.

Denture adhesives should be completely removed from the prosthesis and the oral cavity on a daily basis.

If increasing amounts of adhesives are required to achieve the same level of denture retention, the patient should see a dentist or dental professional to evaluate the fit and stability of the dentures.

While existing studies provide conflicting results, it is not recommended that dentures should be worn continuously (24 hours per day) in an effort to reduce or minimize denture stomatitis.

Patients who wear dentures should be checked annually by the dentist, prosthodontist, or dental professional for maintenance of optimum denture fit and function, for evaluation for oral lesions and bone loss, and for assessment of oral health status.

Use of denture adhesives: Complete dentures are retained in the oral cavity through a complex interaction of factors that include close adaptation of the intaglio surface of the prosthesis to the underlying tissues, appropriate peripheral extension of the denture borders, the presence of a thin film of saliva of acceptable viscosity between the prosthesis and the tissues, and atmospheric pressure. Following tooth removal and denture placement, significant resorption of the residual ridges typically occurs over the first 3 to 12 months. The resportion usually continues at a lower level throughout the life of the patient.[64,66] As bone is lost, the adaptation of the denture to the bearing tissues is compromised, resulting in ill-fitting dentures with compromised retention that decrease the wearer's chewing ability. Denture wearers may have conditions that significantly affect retention and stability of their oral prostheses. In addition to hard- and soft-tissue changes over time, these patients often experience problems with diminished neuromuscular control, reduced bite force, and alterations in the quantity and quality of saliva due to age or medications. Several methods have been developed to enhance both fit and retention of aging prostheses. These methods include denture adhesives, prosthesis relining, rebasing and the use of endosseous dental implants. Denture adhesives are widely available in formulations of creams, powders, pads/wafers, strips, or liquids.

Advantages of using denture adhesives: Twenty clinical trials were identified and reviewed that focused on the use of denture adhesives relative to their effect on denture retention, stability, movement, bite force, ability to chew test foods, food occlusion or patient satisfaction. Most of these studies were of short duration (same-day evaluation). Some trials randomly allocated patients to various experimental groups (depending on numbers of adhesives investigated), and most investigated effects on the maxillary denture only. Some did not have a control group, and many were crossover in design (comparing dentures without adhesives to the same prosthesis with adhesive).

In a study of 146 denture-wearing patients in a dental school in Adelaide, South Australia, Coates[67] found that 52.0% of the patients surveyed saw no need for using denture adhesives, as they managed their dentures well, 20.5% did not know denture adhesives existed, and 32.9% had used denture adhesives in the past, but only 6.9% of those previously using adhesives continued to use them on a regular basis. Instruction regarding denture adhesives and their proper use is important.

Despite limitations, several studies yielded results indicating that denture adhesives improved retention and stability of both ill-fitting and well-fitting dentures.[68–78] Some studies measured the adhesive-related improvement in retention and stability[78–81] and showed more improvement in old or ill-fitting dentures than in new prostheses. However, Grasso and colleagues[76,82] reported no difference in improvement between well-fitting and poorly fitting prostheses.

Regarding mastication, the use of denture adhesives has been reported to significantly improve the bite force a denture patient is able to exert compared with using no adhesives.[79,82–85] Rendell and colleagues[86] further evaluated chewing rates in denture wearers using a multichannel magnetometer tracking device and found that the mean chewing rates increased after application of denture adhesive.[70] Ghani and Picton[74] used subjective measures to evaluate whether adhesives improved chewing ability, comfort, retention and patient confidence in denture wearers.

Functional changes associated with denture adhesive application is time dependent. Rendell et al[85,86] found that chewing improved immediately after applying the adhesive and continued to increase after two and four hours. While many studies indicate that adhesives are effective for up to eight hours, one trial by Kapur et al[76] indicated that the mandibular denture, in spite of showing initial improvements in retention, underwent significant loss of retention following chewing of test foods and imbibing of taste solutions. The duration of effectiveness of adhesive retention is variable and often product dependent.

Improvements in oral health-related quality of life (OHR-QOL): The condition of complete edentulism and

the use of complete dentures have been shown to have a negative impact on the patient's QOL.[87] The effect of denture adhesives on OHR-QOL have recently been reported in a longitudinal study of 14 denture-wearing patients conducted by Nicholas et al.[88] These patients were selected from 143 denture-wearing patients because of their low QOL scores following denture insertion. In this 6-month prospective trial, patients had their QOL assessed at the time of denture insertion and 3 months following insertion. At the 3 month time point, the patients were provided with denture adhesives, and they were assessed again at 6 months following denture placement (3 months after adhesive introduction). They were assessed by means of a Geriatric Oral Health Assessment Index questionnaire,[89] which assesses their OHR-QOL. The results indicated that, while the denture adhesive may have improved the participants' ability to manage conventional dentures and enhance their QOL, no improvement in masticatory performance was found. Thus, while many studies have reported improvements in denture retention and stability with adhesive use, there is limited evidence at this time to suggest that OHR-QOL is improved by using denture adhesives.

Precautions when using denture adhesives: *Cytotoxic effects*. Several articles have evaluated the potential cytotoxic effects of denture adhesives. Two studies were in vitro studies, including studies for evaluating the irritation and cytotoxic potential of commercially available adhesives (creams, powders, and pads). Al et al[90] demonstrated that only one of six adhesive types evaluated induced severe cytotoxic reactions. The authors did, however, raise concerns that adhesives may contribute to mucosal inflammation in denture wearers. Dahl[91] investigated the mucosal irritation induced in vitro by 27 different dental adhesive products. He found that most adhesives damaged the blood vessels of the test apparatus, indicating potential irritant effects on the mucous membranes.

Two in vitro studies revealed both bacterial and fungal contaminants in denture adhesives. Gates et al[92] tested four brands of adhesives and suggested that microwave irradiation of the adhesives for 10 minutes in their original containers may reduce the contaminants. However, in their study, the irradiation had no effect on five of the 24 containers of adhesives tested. The authors recommended caution when prescribing adhesives to the immune compromised patient cohort. Eckstrand and colleagues[93] evaluated 19 commercially available adhesives for microbial contamination and formaldehyde content. Using the agar overlay technique, the authors found that all of the materials tested caused severe cytologic effects. Formaldehyde was found in substantial amounts in four products and in minor amounts in two other products.

In vivo trials have found few negative effects attributed to adhesive use. In a cross-sectional study of 12 maxillary-complete-denture wearers, Kim and colleagues[94] collected samples from the patients' saliva and dentures to evaluate total viable counts of *Candida* sp 2 weeks prior to use of adhesives and after 2 weeks of adhesive use. The authors found no statistical difference between test (adhesive use) and control (nonadhesive use) relative to *Candida* sp counts either in the saliva or on the maxillary denture. They indicated that patient compliance and home care may have played a role in the lack of differences between the groups.

In a similar assessment of 24 denture-wearing patients, Oliveira and colleagues[95] compared the number of colony-forming units (CFUs) and *Candida* sp in saliva samples collected at denture placement and at 7-day and 14-day intervals from patients using an adhesive denture strip. Twelve patients (test group) using the adhesive tape were compared with 12 nonadhesive-wearing patients. There was no statistical difference between the groups at the 2-week analysis. However, neither of these trials evaluated the extended use of adhesives in denture wearers.

Finally, Al et al[90] suggested that since denture adhesives are commonly used throughout the day, denture adhesives may contribute to mucosal inflammation in denture wearers. However, as there are no longitudinal trials of continual use of denture adhesives, the effects of long-term use of adhesives on oral tissues is currently unknown.

Toxicity of zinc-containing adhesives: The most serious of the chronic and excessive use of denture adhesives reported to date is potential neurotoxicity related to the presence of zinc as a component of the adhesive. Zinc is an essential mineral normally found in some foods or used as a dietary supplement. It is involved in numerous aspects of cellular metabolism.[96]

The daily recommended allowances for zinc are 8 mg for women and 11 mg for men, respectively. Acute overdose can lead to nausea, vomiting, loss of appetite, cramps, diarrhea and headaches. Tolerable upper limits of zinc have been recommended at 40 mg per day[95]. Unfortunately, material safety data sheets for denture adhesives do not list the specific amounts of zinc contained by the adhesives. Case-series studies by Nations et al[97] of four patients, and by Hedera et al[98] of 11 patients, identified patients experiencing progressive neurological symptoms (myelopolyneuropathy) following extended chronic overuse of zinc-containing adhesives. This misuse of the adhesives by the patients resulted in hypocupremia and hyperzincemia with resultant neurological symptoms. However, no attempt was made in either study to assess whether the existing dentures exhibited acceptable fit, retention, occlusion and stability, or whether the patients affected were correctly using the zinc-containing adhesives. Both sets of authors identified denture adhesives as the sole source of the neurologic disease. Since these were published, at least one manufacturer has voluntarily removed all of its zinc-containing adhesives from the market as a precautionary measure and replaced them with zinc-free products.

Application and removal of adhesives from the intaglio surface of dentures: There are no studies reported to our

knowledge that have evaluated the patient's ability to effectively place denture adhesives on the intaglio surface of the denture. However, three studies have evaluated the patient's ability to effectively remove the adhesive.

Sato[68] compared the ability of edentulous patients to remove an experimental gel and commercially available cream adhesive from both the intaglio surface of the denture and the maxillary soft tissues. The authors colored the adhesive with 0.4% indigo carmine to allow identification of the adhesive by the patient to facilitate its removal, and also evaluated the patient's ability to remove the adhesive from the maxillary soft tissues using a standardized five-stage method. Each stage involved the use of an undetermined mouth rinse, followed by application of cotton gauze or rinsing with hot water (70 °C) for two minutes; each technique was repeated five times by each patient. The authors found that repeating the process five times did not remove the cream adhesive, while a single stage completely removed the experimental gel adhesive.

A second study, by Uysal et al,[71] of 32 denture-wearing patients evaluated four adhesives in several categories (retention, function, cleansibility, etc.) on newly relined dentures. All adhesives were applied by the investigators, and patients were instructed to use the denture with adhesive for 24 hours. Patients were instructed to clean the dentures with their individual habitual cleaning method, which was not specified. Patients' perceptions were tallied. Although 20% to 30% of patients using each of the four adhesives reported that removal of the adhesive from their oral cavity and denture base was difficult to very difficult, no attempt to assess the degree of cleaning was performed by the authors.

A third study[73] similarly compared the perceptions of 32 patients regarding 10 different factors related to three commercially available adhesives and one formulated by a pharmacy (tragacanth powder). After application of one of the four adhesives and use for 1 day, the patients were interviewed regarding their opinions about the adhesive used. Unfortunately, there was no effort made to verify the patient's ability to successfully clean the tissues or the intaglio surface of the dentures; rather, only the patient's perceptions were collected.

Only the Sato[68] study adequately evaluated the patient's ability to successfully remove the adhesive from the tissues and denture base. Finally, there have been no long-term studies to investigate the potential effects of adhesive buildup on hard or soft oral tissues, if the patient fails to remove the adhesive completely.

Correct application of denture adhesives: The following clinical technique has been advocated by several manufacturers of denture adhesives for proper application to the denture base:

- Clean and dry the intaglio (tissue side) surface of the dentures.
- For the maxillary denture, apply three or four pea-sized increments of denture creams to the anterior ridge, midline of the palate, and posterior border.
- For the mandibular denture, apply three pea-sized increments of denture cream to several areas of the edentulous ridge.
- If using powder adhesive (instead of cream as noted above), wet the base with water, apply a thin film of powder to the entire tissue-contacting surface and shake off any excess.
- If using pad adhesives, place the correct size onto the denture and cut off any excess that extends beyond the denture border with sharp scissors.
- Seat the dentures independently; hold each firmly in place for 5 to 10 seconds.
- Remove any excess material that expresses into the cheek or tongue space.
- Bite firmly to spread the adhesive and remove any additional excess that expresses into the cheek or tongue spaces.

Residual ridge resorption: Multiple factors may lead to bone loss beneath complete dentures. Bone loss is associated with changes that affect the support and adaptation of complete dentures. Loss of alveolar bone, or residual ridge resorption (RRR), is multifactorial in nature. Factors that have been implicated in RRR include local and systemic effectors of bone resorption that include asthma (due to the use of corticosteroid inhalants),[99,100] fluoride consumption, hormone replacement therapy,[101] prior use of removable partial dentures prior to denture therapy,[102] poor oral hygiene,[103] and continuous wearing of dentures.[102,103] In a cross-sectional cohort study of 185 elderly patients in Finland, Xie and Ainamo[100] found that 67% of subjects studied wore their dentures day and night. Acceptable denture quality, as viewed by the examiners, was found to exist in only 10% of the mandibular prostheses and 36% of the maxillary prostheses. Mucosal lesions were found in 16% of the mandibles and 35% of the maxillae. Flabby ridges (suggestive of bone loss) were observed in 24% of the maxillae. The authors found that residual ridge reduction was significantly related to denture quality in both arches, and to prior use of a removable partial denture (odds ratio [OR] = 2.4). There has been one clinical study in humans that demonstrated that leaving dentures out at night, when compared with continual wearing of dentures, resulted in less bone loss beneath the denture bases.[104] However, other studies, including those by Bergman et al[105] and Kalk and de Baat,[106] have failed to corroborate these findings. The Kalk and de Baat study, a cross-sectional study of 92 patients, found a direct correlation between the number of years a patient was edentulous and resorption of the edentulous ridges, and with the number of previous dentures used by

the patient. However, the authors could not find a significant correlation between bone loss and wearing dentures 24 hours a day.

Mucosal lesions and denture stomatitis: In a cross-sectional study of 889 elderly patients in Chile, Espinoza et al[107] found that 574 (nearly 65%) were completely edentulous. Of the entire group of patients examined, 53% of the patients had one or more oral mucosal lesions, the most frequent being denture stomatitis (22.3% of all patients, and 34.0% of all denture wearers). The OR for having oral mucosal lesions was 3.26 for the denture-wearing population when compared with the dentate population. Nocturnal wearing of dentures was associated with an increased likelihood of developing oral lesions (OR = 2.25).

Shulman et al[108] used data from the Third National Health and Nutrition Examination Survey (NHANES III) to explore the risk factors associated with denture stomatitis in the United States. Of 3,450 denture-wearing adults, they found that 27.9% displayed denture stomatitis. The prevalence of developing denture stomatitis was associated with continuous wearing of both the maxillary (OR = 6.20) and mandibular (OR = 5.21) prostheses, as well as with low vitamin A levels and cigarette smoking.

The connection between *Candida* sp and denture stomatitis has been known for decades. Studies by Emami et al[109] and Jeganathan et al[110] have demonstrated the direct relationship between the presence of *C. albicans* and other oral microorganisms and nocturnal denture wear. In Jeganthan et al's[110] study of 75 denture patients, the continuous wearing of dentures resulted in 61% of patients' developing denture stomatitis, compared with 18% of those who did not wear their dentures at night.

In a study of 68 denture-wearing patients from two university clinics, Barbeau and colleagues[111] investigated the relationship between denture stomatitis and *C. albicans*. Risk factors were determined for the patients on the basis of the findings. The investigators concluded that nocturnal wear of dentures and smoking was associated with extensive inflammation of the denture-bearing tissues. Unlike in most studies, the authors could not find a correlation between various *Candida* sp and stomatitis.

Arendorf and Walker,[112] in a matched cross-sectional study of 60 dentate and 60 denture-wearing patients, found that *C. albicans* and related denture stomatitis were found more frequently in patients who wore dentures continually than in those who removed them while sleeping. Similar findings were reported in a short-term evaluation of 24 patients by Compagnoni et al.[113]

The use of nystatin and other antifungal agents has been recommended as part of the treatment regimen to combat *Candida*-related denture stomatitis. A longitudinal controlled trial by Bergendal[114] evaluated the treatment regimen of 48 patients with denture stomatitis compared with 27 patients with healthy mucosa (control group). Treatment of the stomatitis group included fabrication of new dentures, surgical and nystatin treatment, oral hygiene instruction and nutritional counseling. All patients were reassessed after 1 year. The authors found that the use of nystatin did not affect the healing of palatal erythema evaluated 1 year later. Additionally, the nocturnal use of dentures was directly associated with continual presence of denture stomatitis.

Peltola et al[115] examined 42 edentulous patients who had been treated with new complete dentures by dental students in Finland 30 months previously. The authors determined that the frequency of cleaning dentures was not correlated statistically with the condition of the oral mucosa, and those patients who wore their dentures day and night did not have any more stomatitis or hyperplastic changes than those who took them out at night. Finally, a review by MacEntee[116] documented several studies that demonstrated the ill effects of wearing dentures longer than 5 years. The ill effects were primarily related to the presence of soft-tissue lesions.

Relines, rebase of dentures and denture recall interval: The Glossary of Prosthodontic Terms, eighth edition,[117] defines reline as "the procedures used to resurface the tissue side of a denture with new base material, thus producing an accurate adaptation to the denture foundation area." Similarly, the term "rebase" is defined as "the laboratory process of replacing the entire denture base material on an existing prosthesis." While these procedures are seemingly similar, the reline procedure is most often used when factors other than loss of bone or soft-tissue support has changed for the patient (i.e., the vertical dimension, occlusion, phonetics and functionality of the dentures are acceptable), and these changes are compensated for by the addition of new acrylic resin to the intaglio surface of the denture. In those instances in which these other factors have apparently been compromised, the rebase procedure is used. This procedure can effect marked changes in denture architecture that influence vertical dimension, phonetics and associated function. The reorientation of teeth to the denture-bearing surface by means of the rebase procedure provides these potential benefits and at the same time provides a pristine intaglio surface opposing the mucosa.

Unfortunately, there are no published clinical guidelines to assist the clinician in determining how frequently to reline or rebase the dentures. A study by Marchini and colleagues[118] evaluated 236 complete-denture wearers in a Brazilian university dental clinic. They found that only 44% of the patients had sought treatment following completion of the dentures, and that this was at 10 years post completion. Another 23% of the patients had visited their dentist between 6 and 10 years following completion of denture therapy. Additionally, 78% of the patients indicated that they had received no instruction regarding denture cleaning, and 92% indicated that they had not been instructed to return for routine recall appointments. Denture stomatitis

was found in 42% of the patients, although nearly 90% of those affected reported no symptoms. Finally, the authors found a positive relationship between the lack of oral hygiene instructions and the incidence of denture stomatitis. Family income and periodicity of recalls were also directly related to hygiene levels and incidence of stomatitis.

In the Peltola et al[115] study noted in the section earlier, the authors found that the retention of the maxillary denture was "moderate to poor" in 41% of the patients, and that the retention of the mandibular prosthesis was "moderate to poor" in 76% of the patients. The frequency of cleaning of the prostheses did not correlate with the necessity for relining procedures. The overall improvement of denture renewal (in this case, remaking of the prostheses), and improvements in quality and fit of the new dentures was found to have a positive effect on the patients' satisfaction with their prostheses, and on improved health of the denture-bearing tissues.

A finite element study of bone resorption beneath a maxillary complete denture was conducted by Maeda and Wood[119] simulating a poorly fitting denture and a newly rebased denture. The authors postulated, on the basis of their loading study, that RRR in the maxillary arch may be associated with compressive strains developed in the alveolar bone. Rebasing the denture accentuated the stresses, unless the position of the occlusal loads was carefully located (over the lingual cusps of maxillary posterior teeth, not the facial cusps). The authors recommend carefully adjusting the occlusion following rebasing procedures to provide lingual cusp contacts and balanced occlusion in protrusive and lateral excursions.

Recently, a Cochrane Review was conducted by Sutton et al[120] to investigate the effectiveness of denture occlusal schemes in improving patient satisfaction and, thus, in improving the success of the dentures. The authors could only find a single crossover clinical trial of 30 patients that compared a lingualized occlusal scheme with zero-degree teeth that met their inclusion criteria. The authors of this crossover trial[121] did find a statistically significant difference in favor of the lingualized occlusal scheme (OR = 10). However, the Cochrane Review suggested that the evidence was too weak to suggest that cusped posterior teeth were superior to flat-plane prosthetic teeth.

There are no studies to our knowledge that have evaluated appropriate recall intervals for the completely edentulous patient, and few references to what constitutes an appropriate recall interval in published textbooks. Because patient-specific and time-dependent changes of the denture-bearing tissues occur, all clinicians should periodically evaluate each denture wearer for RRR, changes in vertical dimension of occlusion, phonetics, integrity of the denture bases and prosthetic tooth wear, as well as for other biological reasons, including general systemic health, health of the oral soft tissues, oral cancer screening and blood pressure screenings.

FUTURE RESEARCH NEEDS

The ACP Task Force acknowledges that there are significant gaps in the literature related to complete denture care and maintenance. While primarily higher levels of evidence were sought in the search strategy, the task force did not attempt to categorize the reference materials on the basis of the strength of the evidence. Additionally, on the basis of the current level of evidence, the task force recommends that future clinical and laboratory research focus on the following areas:

1. Further exploration of effective cleaning methods will improve the quality of denture use, that is, microwave cleaning. This includes the long-term clinical evaluation and improvement of specific denture-cleaning components for safety, efficacy and ease of use.
2. The impact of denture hygiene on oral and general health requires additional investigation.
3. Proper identification of the inflammatory process in denture stomatitis could enable clinicians to prescribe proper treatments for this condition.
4. The long-term effects (longer than 6 months) of denture adhesive use on oral tissue health need to be determined. Additionally, methods for enhancing the removal of adhesives from the tissue-contacting surface of dentures and oral soft tissues should be developed.

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