An evidence-based review of dental matrix systems

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The restoration of proximal surface cavities, originating from Class II carious lesions, to "normal" anatomical specifications is a fundamental objective for the dental practitioner. Cognitive interpretation of tooth morphology attained from evidence-based resources, together with the necessary psychomotor skills for correct design and completion, are considered essential strategies for restoration success. Also, the visualization of the original tooth structure, if present, should substantially benefit the dentist in the creation of a clinically satisfactory restoration. The purpose of this evidence-based review is to define the cause and effect of decisions based on optimum treatment standards of care for the patient. The concepts of form and function, as related to the oral environment, and the consequences of unsatisfactory dental restorative care will be scrutinized. This article will identify and explain the different challenges and solutions for restoration of dental proximal lesions and provide an overview of past, present, and future procedures.

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The treatment of missing tooth structures can involve myriad choices for the dentist regarding techniques and material resources. The replacement of missing tooth structure lost due to caries, trauma, abrasion, erosion, attrition, or multifactorial causes has always been a subject of concern. Both direct and indirect restorative procedures have advantages and disadvantages.[1] In each instance, the restoration of optimum form and function associated with proximal surface tooth anatomy has included numerous obstacles.[1-4]

A tooth is a living, dynamic organ composed of different tissues and is constantly modifying itself due to the forces of mastication and phonetics.[1,2] Consequently, the reestablishment of optimum form and function directly influences the protection and stimulation of the periodontal apparatus.[1,4] Visualization of the remaining tooth structure and adequate knowledge of accurate tooth anatomy are essential for functional odontologic rehabilitation.[2]

The terms *state of the art* and *standard of care* can be conflicting, yet similar, conceptual entities as applied to the science and art of dentistry. State of the art suggests new products and/or techniques that have been evaluated through in vitro experimentation. However, the use of controlled, longitudinal clinical research methodologies and/or routine implementation by practitioners are prerequisites to establish a pattern of a consistently successful treatment.[5] Standard of care focuses on several aspects of patient care and is defined as "the degree of care or competence that one is expected to exercise in a particular circumstance or role."[5,6] This definition applies to criteria, such as materials and techniques, that have generally been adopted by the profession as clinically effective and successful treatment modalities.[5]

The last 2 decades have brought forth advances in dental material and technique sciences, especially in the rehabilitation of posterior teeth using increasingly esthetic, toothlike restoratives.[2,3,5,7-9] Heightened interest in the general public for a pleasing smile, together with scrutiny by the mass media concerning possible health and environmental effects of dental amalgam—most specifically the release of mercury—has promoted and even elevated the standard of care for the profession.[2,10,11]

Dental professionals have the responsibility for developing multifaceted approaches to proficiently manage all aspects of their clients' care. This practice scenario involves the use of several different cognitive and psychomotor applications for the attainment of qualitative diagnostic and treatment decision-making objectives.[12] These lifelong learning pursuits should include expertise and specialized knowledge in the field in which one is practicing; excellent manual dexterity and practice skills; quality work in services, research, and administrative endeavors; high standards of professional ethics; and a mindset for incorporation of evidence-based learning principles.[13]

Evidence-based methodologies as applied to the field of dentistry consist of a dynamic and evolving integration of education philosophies, such as clinical acumen and expertise, familiarity with the most current research information available, and consultation with the patient resulting in appropriate informed consent.[12-16] This process of lifelong scholarship for the practitioner dictates the utilization of empirical observations, not the acquisition of knowledge through a myopic approach that depends solely on anecdotal concepts and experiences as an information base. However, evidence-based dentistry is also not simply the attainment of knowledge by reading numerous articles. The dental professional must diligently read and understand the results as demonstrated by the procurement of laboratory-based, in vitro outcomes as well as in vivo, longitudinal, clinical trials. Application of this newly gained evidence into daily practice endeavors, along with sound clinical acumen, will result in judicious decision-making abilities and, consequently, prudent patient care.[14]

In keeping with these practice philosophies and conceptual perspectives regarding the art and science of best patient care, the foremost purpose of the present review is an objective assessment regarding the replacement of missing tooth structure, primarily by means of direct restorative techniques and materials. The reconstruction of an intact proximal surface for the purposes of achieving a "normal" or correct surface that has tight contacts and proper contour—with the ultimate goal of maintaining adequate form and function and protecting and preserving the tooth-periodontal complex—will be investigated, beginning with a retrospective presentation of dental matrix systems followed by the most current evidence-based solutions for restoration of posterior teeth.

Dental matrix systems: historical development

Contemporary dentistry must rely on a triad approach to restorative care and should include progressive approaches, such as optimization of tooth form and function, conservation of tooth structure utilizing minimal intervention, and improvement in proficiencies for "esthetic" technologies and material sciences.[2,3,9,17,18]

Continually applied intraoral centric and eccentric functional movements during the processes of mastication, deglutition, and phonetics precipitate constant transposition of the dentition, resulting in increased attritional forces and alterations of proximal contact surface positions.[2,19-22] A proximal contact or contact surface has been described as the "surface area where the proximal faces of neighboring teeth come in contact."[3,23] An acceptably restored dentition requires that the contacting teeth be in close approximation. With the progression of time following eruption, a tooth contact point slowly evolves into a larger contact area.[2,3] The functions of a satisfactory (tight) proximal contact surface include support, alignment, and stabilization of the dentition and the protection of the interdental gingival papilla to prevent food impaction and deter the formation of approximal carious lesions.[3,4,21,24] Establishment of these requirements ensures the optimum protection and stimulation of the oral tissues and consequently a healthy oral cavity.[3,4,7] Absent or open contacts and/or proximal contact surfaces with incorrect dimensions may result in a poorly aligned dentition and displacement of teeth that can cause food impaction, which in turn contributes to halitosis, caries formation, and periodontal disease.[2-4,7,24-29]

Several unique, interdependent anatomical characteristics of the human tooth provide for this dynamic, symbiotic interaction of the process referred to as *protection and stimulation*.[4] These characteristics include correct interproximal form or contour (embrasure shape), optimum proximal contact surfaces, consistent marginal ridge elevations, and central groove continuity within an arch.[4] For realization of appropriate rehabilitative measures that incorporate these features, dental material and technique alternatives must be identified and deliberated based on the etiology of the odontogenic lesion.[3,7,24,25,30,31]

Beginning in the 1800s, restorative dental treatment involved the excavation of a carious lesion followed by filling of the cavity with a material (amalgam or gold), primarily disregarding anatomical structure.[32] Later in the 19th century, the importance of correct contour and contact of an affected tooth was recognized, and restoration of all tooth surfaces, including proximal walls, was deemed necessary.[32] A new concept, *operative dentistry,* was recognized, partially based on the new theory of dental caries and the location of approximal lesions. This progression of circumstances forged the concept of form and function, including the proper contour of proximal surfaces.[1,4,32] Contoured restorations permitted the creation of normal contact surfaces, thus facilitating a healthy tooth-periodontal complex.[1,4,32]

To accomplish the goals presented by these newly conceived dental restorative paradigms, 3 distinct technique advances were proposed: the creation of a separating matrix or band, the development of mechanical separators for gradual separation of teeth, and the placement of wedge devices fabricated from various materials for rapid separation.[2,32] With these components in place, the practice of modern operative dentistry using directly placed filling materials was successfully implemented. The re-creation of natural tooth form and function was finally achieved.

Matrices (bands)

The primary function of a matrix (band) has been to compensate for missing walls and thus provide containment of the filling material.[32] Reconstruction of proximal surface anatomy in dentistry has traditionally been achieved using some sort of *matrix*, which is defined as "that which contains and gives shape or form to anything."[2,33] A *dental matrix band* can be defined as "a properly shaped piece of metal, or other material, inserted to support and to give form to the restoration during placement and hardening of the restorative material," with the re-creation of natural tooth shape and interproximal contact position as the ultimate objective.[2] Traditionally, matrix bands were manufactured from thin, flexible, flat pieces of metal and were placed circumferentially around the affected tooth.[32]

Matrix systems can be categorized based on the type of band and technique of application. Qualifications for all matrix and retainer systems include stability on band insertion and exhibition of adequate style (flat and precontoured) and width (adequate thinness to account for the space taken by the restorative material) for the reconstruction of correct proximal contours and contact surfaces.[2,32] Very early versions of molded matrices were introduced for use with direct filling gold; however, with the

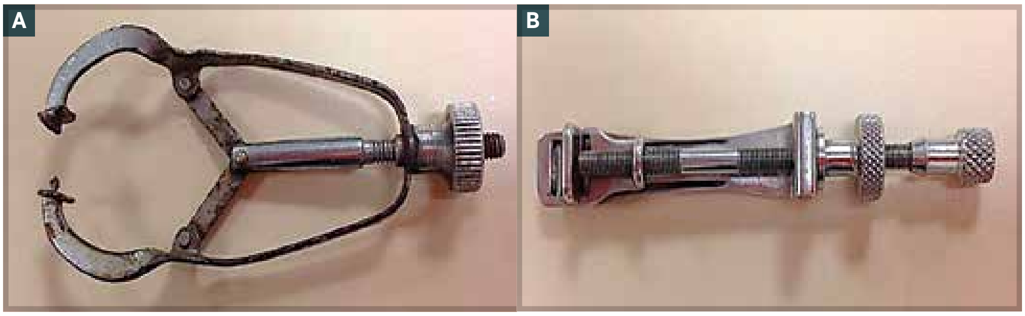

Fig 1. Early retainers produced by J. W. Ivory, Inc. A. The Ivory No. 1 retainer, first produced in 1890 and utilized until the 1960s, employed a screw mechanism for separation of adjacent teeth. The matrix bands were manufactured from thin (0.0015- to 0.0020-inch [38- to 76-µm]) stainless steel. B. The Ivory No. 9 retainer, introduced in 1905, allowed for easier adaptation to the tooth and was the model for the Tofflemire retainer.

Fig 2. Tofflemire retainer and band, developed in the 1940s and still used for placement of Class II restorations.

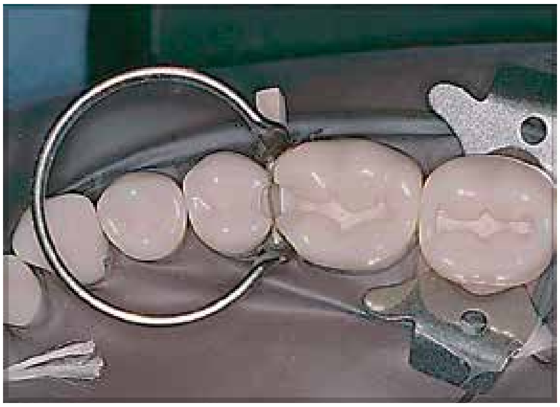

Fig. 3. Restoration of a simulated proximal carious lesion utilizing the Palodent (first-generation) matrix system.

introduction of dental amalgam to the United States in 1830, the development of metal bands was essential to account for the physical properties and condensation characteristics of this new material.[32] Originally, bands were fabricated from pieces of gold or silver; however, improvements in matrix technology focused on bands constructed from tin, brass, copper, and finally stainless steel.[32] Historically, matrices have also been categorized as circumferential or sectional, tie-down, or continuous loop and have been utilized either alone or in combination with a holder or retainer.[32] Many of these matrix systems were indicated exclusively for restoration of Class II lesions with dental amalgam, used together with a small sliver of wood (wedge) and/or a mechanical separator for interdental displacement of the contiguous teeth.[32]

Circumferential, precontoured matrix bands were first introduced in 1871 by Dr Louis Jack for restoration of Class II cavities with dental amalgam.[2,32] The Jack matrix consisted of a small, circumferential, wedge-shaped piece of metal.[32] Following the Jack matrix, several different systems were developed, including the Brunton matrix (1885) and the Huey and Perry matrices (1886).[32] Also, various custom matrix and retainer adaptations were fabricated utilizing novel design elements and materials. Among these early systems were screw-clamp devices, modified rubber dam clamps, the Ivory No. 1 retainer and bands, and the Ivory No. 9 retainer, which abridged band placement around an affected tooth (Fig 1).[32]

The Tofflemire retainer and band (also known as the *universal matrix system*), introduced by Dr Joseph B.F. Tofflemire in 1946, was manufactured as a modified version of the Ivory No. 8 and 9 systems and is still in use today (Fig 2).[1,2,32] The Tofflemire matrix retainer works in conjunction with 3 types of matrices: a universal matrix, gingival extensions, and another matrix with narrower gingival extensions. The matrix retainer comes in 2 thicknesses (0.0020 and 0.0015 inches) and can accept straight and precontoured stainless steel bands. This system can be used in several circumstances but became the most popular system for placement of Class II and compound amalgam restorations. The Tofflemire system produces good contours and contacts for use with amalgam and can also be employed for insertion of composite resin, but more recently developed matrix systems have proven more clinically efficacious, especially for the attainment of interproximal contacts.[1,32]

Alternative "retainerless" matrix systems, incorporating attributes of preformed, spring-loaded, circular bands and novel tightening wrenches, were also developed for the direct restoration of proximal surfaces.[32] These systems have several incarnations, beginning with the continuous loop band.[32] Current designs, known as *automatrices*, are utilized because of their ease of placement, especially for restoration of permanent molars.

Fig 4. Placement of a Triodent V3 matrix system on a simulated preparation.

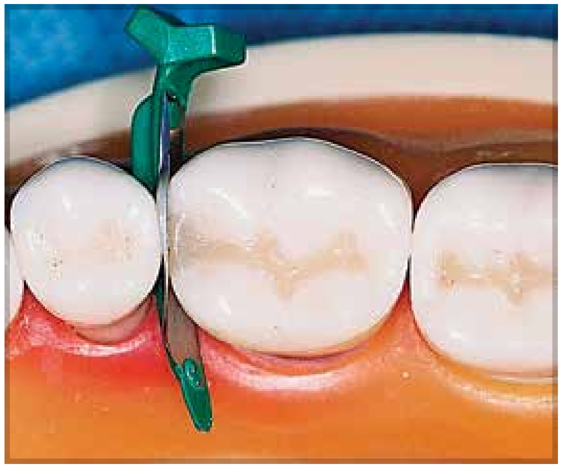

Fig 5. FenderMate matrix system, introduced in 2008, on a simulated preparation. The system includes a contoured sectional matrix and a custom plastic wedge to simultaneously separate adjacent teeth and contain the restorative material.

Mechanical separators

The separation of teeth prior to restoration, achieved by applying pressure or tension between adjacent teeth, is performed to gain access to the lesion, acquire adequate proximal contour and contact, and facilitate the carving and finishing of the restoration.[1] Mechanical separators were first introduced in the 1800s and are still used for acquisition of posttreatment proximal contacts.[32] Examples of early mechanical separators included the Jarvis and Ivory universal double-bow separators, introduced in 1874 and 1886, respectively.[32]

Beginning with the invention by R.M. McKean of the McKean master separator in 1952, a new age and design for the mechanical separation of teeth emerged. The McKean separator employed a spring clamp design primarily used for the orthodontic separation of teeth. The pressure delivered by this device permitted the movement of the tooth and periodontal ligament, allowing for improved separation prior to bracket placement.[2,32] This concept provided a model for later designs, such as the Palodent BiTine ring (Dentsply Sirona) and Meyer sectional matrices, for the establishment of proximal contacts with dental amalgam.[2,24]

The development of the McKean principle of interdental separation has evolved into several generations of spring clamp or separation ring systems manufactured specifically for the insertion of Class II composite resin restorations.[3,24] Ring matrix systems include a separation ring, sectional matrices, custom-fitted plastic wedges, and application forceps. As the ring is expanded and its tines are placed over the contact area between the teeth, the spring action applies equal and opposite forces against the teeth, providing optimum separation. Upon polymerization of the composite resin, the ring is removed and the teeth are brought back into contact.[3,34] The Palodent BiTine matrix system was introduced in the 1990s and was the first generation to utilize this concept exclusively as the restoration of posterior teeth using composite resin increased.[3] The Palodent sectional matrix and ring system utilized a very thin (0.01-mm), contoured sectional matrix together with custom-fitted wedges and metal rings, employing tension between the teeth after placement of the matrix (Fig 3). This technique effected the separation of the adjacent teeth for improvements in the acquisition of optimum proximal contacts, especially in conjunction with the use of composite resin.[3,24,34] On separation, tooth displacement is achieved (oppositely), with a maximum interdental separation of about 0.55 kg/mm. This technique demonstrated a short-term elastic response of approximately 1 minute, followed by a long-term viscous response of approximately 30 minutes.[31]

In 2008, Dr Simon McDonald introduced the Triodent V3 system (Ultradent Products, Inc), a nickel-titanium ring design with plastic tine grips, together with custom wedges and WedgeGuards for acquisition of improved proximal contact surfaces (Fig 4).[35] An updated design, the Triodent V4 system (Ultradent Products, Inc), has introduced improvements in materials and ease-of-use characteristics, with elements such as ClearMetal matrices (Ultradent Products, Inc) that offer microwindows for increased polymerization capabilities. The Palodent Plus matrix system (Dentsply Sirona) is similar to the Triodent system and has also shown improvements in ring and matrix technology.

These innovative devices, re-created and refined by numerous dental instrument manufacturers, are currently experiencing third- to fourth-generation adaptations based on modernizations in ring and matrix design. Advancements in ring, matrix, and wedge design have allowed for improvements in gingival adaptation, contact surface anatomy, ease of use, and inclusion of wider (buccolingual) proximal contours.[3,31,34-38]

Miscellaneous designs and modifications employing various combinations of different types of matrices, wedges, and separation techniques have also been developed. The grouping of a precurved, sectional matrix band and a wedge (without the use of a separation ring) into 1 apparatus, as demonstrated in the FenderMate system (Directa Inc), has recently been marketed (Fig 5). These systems do provide the dentist with fewer moving parts but are expensive and can possibly produce problematic clinical results.[39]

Discussion

The satisfactory rehabilitation of a proximal surface due to missing tooth structure requires the fulfillment of several criteria, including attainment of anatomically correct contour and contact area, marginal adaptation at the material-tooth interface, and accurate marginal ridge placement.[1-4] The visualization of existing tooth structure (if present) prior to restoration is fundamental for correct reconstruction of both anatomical (form) and stomatognathic relationships (function).[2] If any of the criteria are not considered and implemented during restoration, the tooth-periodontal complex can be negatively affected. Restoration of teeth to natural form and function, through either direct or indirect procedures, is essential for optimum maintenance of this oral complex.[1] The intraoral activities of prevention and stimulation are therefore based on the adherence to the correct attainment of these restorative criteria.[1-4]

An ideally reconstructed proximal surface, taking into consideration both anatomical and occlusal factors, aids in the prevention of food impaction and subsequent periodontal disease.[3,4,7,21,24] The stimulation of oral tissues and/or stabilization of the dentition within an arch and the opposing occlusion are achieved through correctly applied principles of current, evidence-based methodologies.[3-5] In modern restorative dentistry, anatomically correct contoured restorations, allowing for well-maintained functional roles, rely on tested materials, armamentarium, and techniques.[2,3,5,7-9]

A study conducted by Lynch et al concluded that the restoration of posterior teeth (2 and 3 surfaces) with composite resin outnumbered placement of amalgam fillings in the United States.[40] Also, almost one-half of posterior intracoronal restorations placed by dental students in the United States and Canada consisted of composite resin.[40] The same survey stated that, within a 5-year period, 58% of posterior restorations included composite resin.[40]

Composite resin has achieved prominence as a posterior, Class II, direct restorative material partially due to numerous advancements in material properties as well as preparation and restoration techniques.[1,41-43] Improved physical qualities, such as increased strength, greater wear resistance, enhanced esthetics, decreased postpolymerization, and decreased volumetric shrinkage, are among the characteristics of currently used materials.[1,41-43] Longitudinal studies and randomized clinical trials have shown that the survival rates of posterior composite resin restorations have approached the levels of dental amalgam.[44-47]

Although properties of composite resin have evolved with time, difficulties persist regarding the insertion of these materials, especially factors related to placement in the posterior dentition. Operator skill, insertion techniques, bonding regimens, and polymerization protocols are still the primary factors for successful treatment outcomes.[1,48-50] Evidence of marginal discoloration ("white line") and sensitivity are still posttreatment patient concerns, while other influences—including the configuration factor (C-factor)—are also adversities for practitioners to overcome.[1,51-53]

One of the primary challenges for the dentist when restoring posterior teeth using composite resin includes the establishment of anatomically correct proximal contacts.[24,54] Open (light) proximal contacts can lead to food impaction, which, in turn, interrupts the natural cleansing process and advances the breakdown and failure of the periodontal components as well as the restoration.[1-4,7,55,56]

No objective description of a clinically acceptable proximal contact surface, for either diagnosis or postrestoration evaluation criteria, has been clearly defined in the literature.[2] The practice of flossing has traditionally been the method for the evaluation of proximal contact acceptability, with designations of *tight, weak,* or *open* as qualifying discernments.[2,44,57] Although this method is a practical clinical approach for determination of postrestoration form and function, variables such as floss design and appropriate degree and direction of force are subjective factors that can produce inaccurate results.[25]

Several different approaches have been developed to objectively measure the interproximal tooth position or restoration surface contour pressure.[2,36,37,58-60] Among these are interdental metal strips, a digital tension transducer, a tooth pressure meter, and 3-dimensional (3D) imaging for measurement of the interproximal force and interdental frictional forces.[2,58-60] Although these techniques can serve as tools for quantitative measurement with resultant objective data, application of these procedures in a dental practice may not be feasible.

A tight, well-contoured proximal contact surface has traditionally been more easily achieved through the use of dental amalgam due to the favorable material physical properties of condensability and expansion factors as opposed to the polymerization shrinkage and other deleterious factors associated with composite resin.[1-3] With improvements in material science and application technology in the last 2 decades, the shortcomings associated with the increased usage of composite resin for the restoration of posterior teeth have diminished but are not totally resolved.

In order to further reduce the complexities associated with the reconstruction of proximal contact surfaces, much attention has been assigned to the development of different matrix systems to alleviate the intricacy attributed to insertion of composite resin.[1-3,7,60-65] Current matrix systems, especially for use with composite resin, employ custom wedges and interdental separation devices, diverse contact ring designs, and distinctive band styles.[1-3,7,60-65] These systems include the capability for customization to account for the variability of the proximal surface anatomy of human teeth. Precontoured or sectional matrix bands allow for an anatomically correct surface, but, in the absence of a displacement force such as that created by a separation or contact ring, the band retains a memory quality upon initial insertion of the material, thus forming a suboptimal contact surface contour.[1-3,7,24]

Proximal contacts (area and strength), interproximal marginal interfaces (overhangs and other deficiencies), and marginal ridge contours (shape and strength) have been criteria studied to determine if a reproduction provides for the correct anatomical and functional service of a tooth.[7,60-63] In vitro and in vivo research has measured the effects of different matrix systems, including matrices (sectional vs circumferential), wedges, and separation rings, as well as different insertion techniques (incremental vs bulk) and materials, on various aspects of Class II restorations.[7,24,30,31,37,38,54,55,60,61,64,65] All these studies concluded that each interproximal matrix system has certain advantages and attributes as well as disadvantages and deficiencies. A study by Chuang et al that evaluated current matrices and separation systems using 3D imaging concluded that both systems showed problems regarding proximal contour and contact tightness.[60] Thin, sectional matrices provided for tight interproximal contacts but concave contours, while circumferential bands produced flat contours but decreased the occurrence of marginal overhangs. The same study also revealed that it was the particular matrix system and not the composite resin material that primarily affected the tooth anatomy and thus the success of treatment.[60] Separate studies have shown that the use of sectional matrices and separation rings for insertion of Class II composite resin restorations resulted in stronger contact surfaces compared to the utilization of traditional circumferential (Tofflemire) bands and wood wedges.[31,37,38,60-62,66] However, a study conducted by Loomans et al concluded that the use of Tofflemire matrices resulted in less overhang than did restoration using sectional bands.[62]

Conclusion

Evolutions in material formulations, refinements in insertion techniques and armamentarium, and the gradual replacement of dental amalgam with composite resin has advanced the science of posterior, direct placement restorative technology. Composite resin has replaced dental amalgam as the posterior restorative material of choice, although persistent challenges are still encountered by the practitioner, primarily due to material properties and armamentarium. The usage of more traditional restorative techniques (such as Tofflemire matrices and wood wedges) in conjunction with current materials (such as composite resin) may lead to clinical failure and decreased longevity of these restorations. As a result of the complexities involved with the placement of composite resin in the posterior dentition, novel developments in matrix system technology have emerged, such as improvements in matrix design and interdental separation techniques. These innovations have allowed the dentist to achieve the most advantageous proximal contact surfaces and anatomically correct contours—so important for optimum form and function of the dentition as well as for stimulation and protection of the periodontal complex.

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