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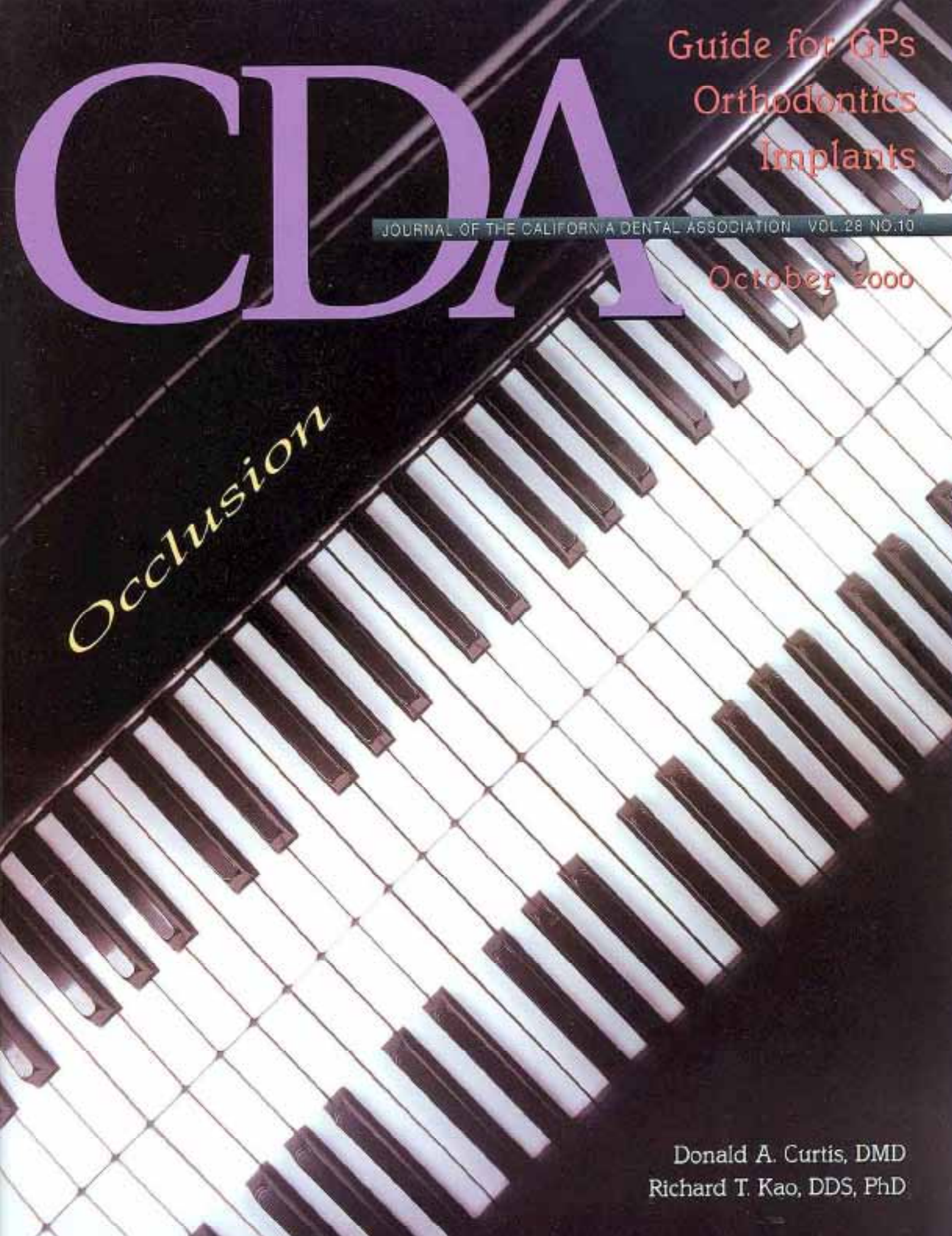
Guide for GPs
Orthodontics
Implants

Occlusion



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DEPARTMENTS

FEATURES

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Achieving Consensus

Jack F. Conley, DDS

The CDA Applied Strategic Planning Committee completed the majority of Phase I of the 2004 Strategic Plan for the association with its draft report to the Board of Trustees in mid-August. The Board accepted that report, which includes a vision statement, a mission statement, core values, and goals for the association.

Yet to be completed in Phase I at the time of this writing, is a review of feedback received from shadow teams and the Board that was the subject of discussion at a final meeting of the committee on Sept. 9. Shadow teams of association stakeholders (people with an interest and stake in the outcome of the Strategic Plan), representing a wide range of association membership interests, were identified by each of the 25 members of the committee. The role of these groups was to provide feedback to the committee during its development of the Strategic Plan. At the September meeting, the committee completed minor modifications and editorial revisions based upon the feedback it received, completing Phase I of the Applied Strategic Planning process

The process has now entered Phase II, with the effort to inform component society leaders and delegates and other interested members of organized dentistry about the plan in advance of the 2000 CDA House of Delegates next month in San Diego. The proposed 2004 CDA vision, mission, core values, and goals will be placed before the House of Delegates for adoption, which is Phase III of the process. Phase IV -- implementation -- is the ultimate objective once the elements of the plan have been adopted by the CDA House.

In the spirit of the education and membership goals of the Strategic Plan, we believe that dissemination and review by interested members is important at this time. Therefore, we are providing a brief summary along with comment in this space. Your comments should be directed to the members of your component society delegation well in advance of the Nov. 19-21 session of the CDA House of Delegates.

In our opinion, the new vision, mission, and core values statements (see box) for CDA have been carefully developed by the Applied Strategic Planning Committee and should be embraced by all membership. Taken together, they provide an excellent foundation for the future of organized dentistry in California.

Goals and objectives that address the first section of the plan, corporate operations, may not immediately hold the attention of the membership at large. However, they speak to the importance of achieving shared visions and guiding practices of all subsidiaries and departments of the association, the adjustment of internal staff structure, and the commitment of all employees to serve the best interests of the members of the California Dental Association.

Governance goals and objectives include a restructuring of the volunteer leadership, a recruitment and training program to develop a corps of qualified and effective leaders, and a fully operational charitable and educational foundation. In this space, we have commented annually about the lack of a more robust pool of volunteer

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Proposed Strategic Plan

CDA Vision
CDA, celebrating the diversity and unity of the dental family, is the source of inspiration, motivation, empowerment and pride for all oral health care professionals. The organization embodies a spirit of respect, synergistic cooperation and commitment. Through public policy and advocacy, education and other means, CDA promotes the health of the public, the profession and the individuals it serves.

CDA Mission
The mission of the California Dental Association is to be the recognized symbol of excellence in education, advocacy and innovation, serving its members and assisting the dental community in their responsibility to the public.

CDA Core Values
Service
Respect
Education
Inclusive
Integrity
Oral health and its impact on overall health

leaders. Implementation of this part of the strategic plan is vital to an effective organization in the future. A good training program in leadership skills is also fundamental to a successful, volunteer-driven organization.

Central to the education section of the Strategic Plan is development of a learning center concept, which uses existing CDA educational vehicles such as publications, Online, and Sessions. It expresses a commitment to lifelong learning and year-round virtual distance learning, including interactive continuing education programs. Included in the plan are implementations of system protocols for exchange of pertinent information, which will allow a continuum of information that ranges from responses to basic member inquiries, to comprehensive educational information. It also speaks to an association commitment to support efforts of the dental schools to obtain necessary funding to fill faculty openings with quality people. Another goal seeks support for continuous quality improvement (and the QUIL3 program) by the membership if CDA is to effectively convey to the public the benefit of choosing a CDA member dentist. This goal also speaks to an effective public relations program by CDA regarding these initiatives.

The membership goals include a comprehensive membership resource center that provides exceptional service and programs that are desired by the membership. It will seek to survey what members need and want on an ongoing basis. Also included is a contact center to provide response to membership inquiries and a plan to maintain interactive cooperative meetings for the membership, including virtual, Web, town hall, and face-to-face. Another membership goal directly seeks to increase CDA membership to represent a greater percentage of dentists and reflect the diversity of licensed dentists in California. This goal focuses on recruitment of students at all educational levels to careers in dentistry, development of an innovative dues structure that raises the perceived value of membership, and a membership recruitment plan for dental faculty.

Several other membership goals include activities often requested by the association members, including an aggressive marketing program, addressing the allied dental health personnel needs of members, and an ombudsman program to assist them in dealing with third-party payer issues. The committee also recognized a severe professional problem area when they vowed to form collaboration with entities such as health care foundations, dental schools, and the legislature to consider student debt issues and formulate a plan to address this significant problem for younger practitioners.

Public policy goals are also an important part of the Strategic Plan. They include aggressive representation of the profession by the association and the promotion of the health of the public before legislative and regulatory bodies in order to become recognized as the respected voice on oral health issues. CDA would become established as a leader in improving access to oral health care services, be recognized as a major player in influencing the outcome of legislative elections, and ultimately seek to create a new win-win-win model of dental reimbursement.

The rationale for strategic planning provided by the committee provided some principal reasons why this process is important to organized dentistry in California. Three of these impress us with their importance based upon our observations of the workings of the association in recent years. First on the list is "to better represent and serve the members," followed by "to raise the perceived value for membership in CDA among all California dentists." We believe that the first will lead to the second. Various sources of input have clearly shown a need for improvement of the

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services received by the membership. The membership today expects an increased level of representation and advocacy from the association that has not been part of the traditional mix. The plan, in our view, effectively addresses the needs that have been frequently expressed.

The other reason that jumps out in support of this plan is "to create continuity of purpose and action across all levels of CDA." In our experience, purpose and efficiency are essential if we are to make the best uses of our resources. The CDA family of companies has experienced difficulty in recent years making the best use of our efforts and resources. In the development of this plan, we have seen the evolution of a new commitment by staff and volunteers to develop a focus that will help to address these previous shortcomings.

Dentistry, and the world that influences it, has been radically changing, requiring that dentistry change its modus operandi. The membership has been aging, and the expectations of younger members regarding association service and value are different. If organized dentistry is to have any success in meeting the challenges of today and tomorrow, it must transition to a new approach of doing business. The last two decades of the 20th century were periods of remarkable growth for CDA that are unlikely to be repeated. Just like the individual dental office, the association needs to focus its efforts and resources if it is to successfully face the new challenges of the 21st century. In the past, organized dentistry maintained a strong voice, as it was able to represent about 80 percent of the dental profession. This segment of the dental population has been eroding in the past decade. Failure to increase our ranks and resources will result in an organization that fails to address the needs of members.

Additional details describing the Applied Strategic Plan were included in the September CDA Update. Take the time to review them and advise your local leadership and delegates to the House of your opinions regarding the plan. The accomplishments of the profession in the years ahead depend upon participation and support at every level of the membership.

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Building the Multi-Generation Dental Team

By Debra Belt

How would you describe your outlook? How about your work ethic or view of authority? There's a good chance that when you were born affects your perspective on such things.

You may be a "traditionalist," born before 1946, with a tendency toward a practical outlook, dedicated work ethic, and respectful view of authority. Perhaps you're a "boomer," born between 1946 and 1960, with an optimistic outlook, driven work ethic and love/hate view of authority. Or maybe you're part of "Generation X," born between 1960 and 1980, and tend toward a realistic outlook, balanced work ethic, and unimpressed view of authority.

No matter where you fall on this generational scale, one thing is certain. All three groups come together in the workplace. For dentists, integration of the generations on a team is essential as California and the nation face a shortage of dentists, hygienists, and dental assistants. In light of this, leaders in dentistry are focusing on today's employees and what motivates them to enter and stay in the profession.

Generational attributes and expectations were the focus of the sixth annual Allied Dental Health Symposium "Generation X and The Dental Team" presented in July by CDA's Council on Education and Professional Relations. Attendees included leaders in dental hygiene, dental assisting and dental laboratory technology as well as CDA President Kent Farnsworth, DDS, and President-Elect Jack S. Broussard, DDS.

The symposium facilitator and keynote speaker, Kathleen Shanel-Hogan, DDS, MA, is concentrating her current PhD studies on transformative learning and change. "When working with different groups, you encounter different expectations," she explains. For instance, "I identify with the 'boomer' work ethic where I get out there and work hard; if someone asks for nine yards, I give them 10. However, it can cause dissonance if I place the same expectations on someone else who is prepared to give nine yards when asked for nine yards, eight hours of work when asked for eight hours. That's why it's important to clarify expectations of employees and employers; to give both parties a chance to address their needs and feel like they've been heard."

Pieter Linssen, DDS, a 1997 dental school graduate says he has found respect and positive relationships as an associate working with two private practices in Placerville and Granite Bay, Calif. "Both offices foster a family atmosphere and respect is given to all members of the teams. They are both smaller practices, with fewer than 10 people, and you get a chance to know people and find out about their thought processes."

He admits that in some cases he has had to relax his expectations a little bit. "If you constrict someone in a business sense, you constrict them in an artistic sense as well. Someone may not have the exact technical expertise I want, but he or she may have a positive attitude or other attribute I would never want to restrict."

Linssen says he has found pros and cons to working with both younger and older team members. "Older colleagues offer wisdom and experience. They have seen everything. On the down side, there may be resistance to new ideas. With younger team members, there is enthusiasm; they want to learn and see everything. On the other hand, there is the lack of experience."

Shanel-Hogan points out other variances in perspective that can result from coming of age in different decades. "'Gen X' had different role models as they were growing up; they have witnessed authority figures who have slipped and fallen, and they have seen their parents be 'downsized' by companies they were loyal to for many years. They tend to have a more realistic view of things. A 'boomer' may view this as cynical." Or a young team member may ask why things are being done a certain way and a more traditional person could see this as a challenge. Also, 'Gen Xers' have

Low Vitamin C Can Increase Risk for Periodontal Disease

People who consume less than the recommended dietary allowance for vitamin C have slightly higher rates of periodontal disease, according to a study in the August issue of the Journal of Periodontology.

Researchers analyzed vitamin C intakes and periodontal disease indicators in 12,419 U.S. adults. They found that patients who consumed less than the recommended 60 mg per day (about one orange) were at nearly 1 1/2 times the risk of developing severe gingivitis as those who consumed three times the RDA.

Researcher Robert Genco, DDS, PhD, chair of the Oral Biology Department at the State University of New York at Buffalo, says the relationship between severe vitamin C deficiency and gum health has long been known. "In the late 18th century, sailors away at sea would eat limes to prevent their gums from bleeding," Genco said. "The relationship between vitamin C and periodontal disease is likely due to vitamin C's role in maintaining and repairing health connective tissue along with its antioxidant properties."

"Periodontal disease is an inflammatory disorder that increases tissue damage and loss. Since vitamin C is known as a powerful scavenger of reactive oxygen species, which form part of the body's antioxidant defense system, low levels of dietary vitamin C may compromise the body's ability to neutralize these tissue-destructive oxidants," Genco said.

been criticized for being materialistic when often they are concerned about money due to large educational loans hanging over their heads.

"When I went through school, tuition and fees were $3,200 a year," Shanel-Hogan says. "It's hard for me to image students coming out of school with $100,000 or more debt, but I would want them to know I understand their situation."

"My generation's greatest fears are failure and lack of security," says Linssen, who contributes these fears to coming of age in the late 1980s when the economy wasn't as strong, and families were experiencing an unprecedented boom of divorce. "In dentistry, the opportunities to start a new practice are not nearly as bountiful as they once were. The cost of education and technology places a lot of limits on start up."

Still, Linssen says he has a positive outlook on his career, even though his generation has a tendency to define success in a different way than previous generations. "It's becoming harder and harder for us to define ourselves. I hear a lot of people my age saying: 'I will never work 8 to 5 or have a desk job.' It seems that the opportunity to travel and do more 'soul-searching' is important now. I feel fortunate that dentistry offers not just a chance to make a living but a lifestyle."

Despite the departure from a more traditional view of success, Linssen says that qualities like work ethic are very individual. "Work ethic comes from what you were taught growing up."

Shanel-Hogan also notes that the qualities and characteristics of different generations are just "starting points for discussion." When we talk about differences, it's just as important to find out about differences between individuals."

In her presentation at the symposium, Shanel-Hogan included information from the book Beyond Generation X, a guide for managers by Claire Raines. "Claire talks about the most frequent requests 'Gen Xers' make of their managers (see sidebar). This is a good place for dentists to start for ideas; take a look at this list, brainstorm ideas about how it might work and then talk to staff members."

Building these trans-generation skills will also be helpful for communicating with the up-and-coming "Generation Y."

The seven most frequent requests "Generation Xers" make of their managers:

- Show your appreciation.
- Be flexible and try to understand that "Xer's" don't consider jobs to be their lives.
- Create a team environment.
- Help develop skills.
- Involve your team in decision making.
- Keep a perspective and lighten-up!
- Set an example.

Recognizing Burning Mouth Syndrome

Burning mouth syndrome has been described as a complex of many symptoms with very few signs and multiple etiological contributing factors. Although it is often not definitively diagnosed, dentists should take the condition seriously and perform diagnostic testing to rule out causes, treat the symptoms, and attempt to arrive at a true diagnosis, according to an article in the May-June 2000 issue of Northwest Dentistry.

Burning mouth syndrome is characterized by chronic (at least six months), continuous, progressive, unexplained pain, the authors state. Estimates are that more than 1 million people in the United States suffer from the condition.

Possible explanations for the symptoms of burning mouth include ill-fitting dentures, nutritional deficiencies, disturbances in salivary flow, and hypersensitivity to dental materials. Usually no single factor is entirely responsible.

Dentists must rule out as many of the potential contributors as possible, the authors said. When no clear etiological factor is found or only minimal relief is obtained by treatment of the identified contributors, then the default diagnosis of burning mouth syndrome is customarily made. However, after diagnostic testing to rule out causes of oral burning symptoms and/or treating those symptoms with some success, a definitive diagnosis of true burning mouth syndrome may emerge.

According to the authors, it appears that true burning mouth syndrome is a neuropathic disorder, or hyperalgesia. The study also indicated that hormonal activity may play a role because all the patients studied had significantly lower than normal estrogen and progesterone levels.

Physicians Reclaim Practices at Bargain Rate

As physician practice management companies continue to struggle financially, many physicians are buying back their practices, sometimes at bargain prices.

According to a story in the Aug. 21, 2000, issue of American Medical News, the newsletter of the American Medical Association, many physicians are now buying back their practices from both practice management companies and hospital systems at prices far below the original price paid to acquire the practices in the first place.

For example, MedPartners, a now-defunct practice management company, paid the 120 members of the Talbert Medical Group in California $95.2 million to buy their practice. Just a few years later, in 1999, the medical group bought the practice back for $3.7 million, only $31,000 per physician.

Poor performance explains the bid of practice management firms to jettison their assets, according to Robert Bohlman, a consultant with the Medical Group Management Association. However, the practices most often being sold back are those owned by hospital systems. Eighty percent of hospitals that bought practices -- to ensure a flow of referrals -- lost money in the millions per year. Many hospital systems have decided to get out of the business of owning physician practices.

Smoking Bans Send Kids the Message

Parents may be able to reduce the chances that their teenagers will take up cigarettes by banning smoking within their homes, even if they smoke themselves, according to a study in the British Medical Journal.

A survey of more than 17,000 U.S. high school students found that restricting smoking at home, at school, and in public places appears to reduce teen smoking.

"Smoke-free environments lead to smoke-free kids," said Dr. Melanie A. Wakefield, the lead author of one of three studies on secondhand smoke and children published in the Aug. 5 issue of the British Medical Journal.

The link between smoking restrictions and reduced teen smoking was strongest for smoking bans set by families in their homes, the report said.

"Communities that pass strong laws to restrict smoking in public places will not only be protecting their residents from the effects of environmental tobacco smoke, but can protect their children from becoming smokers," Wakefield said. "If you are a parent, banning smoking inside your home can decrease the chances of your child taking up smoking. This applies even if you are a parent who smokes."

Transplant Recipient Using New Hand

A 38-year-old man who received a hand transplant was able to write and tie his shoes one year after the surgery, according to an article in the Aug. 17 issue of the New England Journal of Medicine.

Four months after the first human hand transplantation surgery in France, a similar operation was performed at the Jewish Hospital of Louisville, Ky. The left hand of a 58-year-old male, matched for size and skin tone, was transplanted to a 37-year-old man who had lost his dominant hand 13 years earlier.

Although moderate acute cellular rejection of the skin of the graft developed six, 20, and 27 weeks after transplantation, all three episodes resolved completely after treatment.

By one year, temperature, pain, and pressure sensations had developed in the hand and fingers. In addition, the patient was able to perform many activities he was unable to do with his prosthesis, including throwing a baseball, turning the pages of a newspaper, writing and tying his shoelaces.

Honors

Paul A. Reggiardo, DDS, has been awarded the American Academy of Pediatric Dentistry's 2000 Merle C. Hunter Leadership Award. He is in private practice in Huntington Beach, Calif.

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Current Issues in Occlusion

DONALD A. CURTIS, DMD, AND RICHARD T. KAO, DDS, PHD

Occlusion plays a central role in the practice of dentistry. However, the scientific basis for many occlusal procedures has remained controversial. For example, in the 1980s, occlusion was popular as testimonials supported its importance in oral rehabilitation, periodontal disease progression, and craniomandibular pain. Empirical theories and clinical strategies were developed that perhaps overstated the importance of occlusion.

In the late 1980s, epidemiological studies questioned the scientific basis for many relationships between occlusion and dysfunction. This resulted in confusion, a loss of interest, and even a backlash in the sentiment of the profession. Within a short period, the topic of occlusion was not only unpopular, but also considered unscientific and superficial hyperbole. The goal of this issue is to emphasize that occlusal considerations are important and that science has shown a well-established association between occlusion and dental health.

This issue of the *Journal of the California Dental Association* includes five papers intended to update practitioners with new information about the relevance of dental occlusion to their practice. The first article describes the evolution of numerous theories, techniques, and treatment philosophies as related to occlusion. Though some of these ideas have been disproved, others remain empirically true, while others have been validated by scientific evidence.

The second article outlines how occlusion can affect treatment prognosis. As the tooth-periodontium apparatus weakens through disease and over time, adaptive changes occur in response to occlusal force. Strategies for improved adaptive response are discussed. This article takes an original approach in looking at occlusal force as a prognostic determinant of treatment outcome.

The third article reviews the use of dental implants in the partially edentulous patient. The article emphasizes the importance of treatment planning and how attention to occlusal relations can decrease restorative complications. Both the type and frequency of restorative complications are reviewed, as are considerations for splinting and cantilevers with implant restorations.

The fourth article outlines why most referrals for orthodontic treatment are occlusion-related and why the importance of occlusion continues to be controversial in orthodontics. The six warning signs of a child with a developing malocclusion are reviewed, and how unfavorable growth patterns can be altered with early treatment is emphasized. Included is a discussion of current thinking on the relationship between temporomandibular joint dysfunction and orthodontics.

The last article offers the clinician a simple and practical classification system that can assist in the diagnosis, treatment planning, and management of occlusion. This classification system has been successfully used in our teaching program at UCSF.

We hope you enjoy and benefit from this issue on occlusion.

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Occlusion: What It Is and What It Is Not

Charles McNeill, DDS

ABSTRACT Dental occlusion is much more than the physical contact of the biting surfaces of opposing teeth or their replacements. Occlusion is more comprehensively defined biologically as the coordinated functional interaction between the various cell populations forming the masticatory system as they differentiate, model, remodel, fail, and repair. Morphologic variations are very common and represent the norm. Even though the occlusal or musculoskeletal relationship may not meet the definition of the clinician's concept of an optimum or ideal occlusion, it must be appreciated that for that particular patient, the tissues of the masticatory system may have developed a stable, functional, healthy, and comfortable equilibrium. However, when the functional equilibrium is perturbed or when the occlusion is being re-established, specific treatment criteria are as important today, if not more important with the rapid growth of implant placements, as ever before. Treatment of the occlusion should be considered on an individual basis based on the specific physiologic needs of the various tissue systems within the masticatory system rather than on a preconceived, stereotyped or universal basis. It has long been established and recently proven that proper management of the occlusion is directly correlated to the successful treatment and maintenance of the teeth and, at times, the supporting tissues. On the other hand, it has not, to date, been scientifically proven that occlusion is directly correlated to the musculoskeletal disorders that affect the jaw (temporomandibular joint or masticatory muscle disorders).

AUTHOR

Charles McNeill, DDS, is a professor of clinical dentistry and director of the Center for Orofacial Pain at the University of California at San Francisco School of Dentistry.

Occlusion is most appropriately defined as the functional relationship between the components of the masticatory system including the teeth, supporting tissues, neuromuscular system, temporomandibular joints, and craniofacial skeleton.[1] The masticatory tissue systems function in an integrated and dynamic manner in which stimuli created by function signal tissues to differentiate, model, and remodel. The behavior of the cell populations in these tissue systems is determined by the biological environment. When there is a perturbance to this dynamic functional equilibrium due to injury, disease, adverse functional demands, or a loss in the adaptive capacity of the tissues, tissue failure can occur. However, the cell populations of the various masticatory tissue systems have great potential for physiologic repair, reducing the demand for treatment. Thus, occlusion should be defined physiologically

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not morphologically. Occlusion should not be defined simply, as in most dictionaries, as any contact or relationship between the incising or masticating surfaces of the maxillary and mandibular teeth and/or dental arches.[2] Occlusion is not a static, unchanging structural relationship, but rather a dynamic, viable physiologic relationship among the various tissue systems. When this viable equilibrium is disrupted or injured, the resulting occlusal discrepancies can adversely affect the teeth and, at times, the supporting periodontal tissues. However, occlusal discrepancies, especially ones that have developed over time, have not been proven to be the cause of musculoskeletal disorders affecting the jaw. Conversely, occlusal discrepancies can be the effect of a jaw disorder, for example, osteoarthritis of the tempormandibular joint causing a collapse of the posterior occlusion on the affected side.

Occlusal Classification

Occlusion can be classified into three general types of physiologic stages as follows:[1,3-5]

- A physiologic occlusion commonly termed a "normal" occlusion suggesting that disease and/or dysfunction are not present and treatment is not required;
- A nonphysiologic occlusion, commonly referred to as a "traumatic" or "pathologic" occlusion suggesting that limited disease and/or dysfunction is present and treatment may be required; and
- A treatment occlusion often referred to as an "ideal" or "therapeutic" occlusion suggesting that specific treatment criteria are required to treat the effects of trauma or disease.

An integrated diagnostic rationale based on an adequate collection of information from the patient's history, clinical examination, and other indicated tests is required to appropriately categorize and manage the three different types of occlusion.

Physiologic Occlusion

A physiologic occlusion is defined as an occlusion in which a functional equilibrium or state of homeostasis exists within the tissues of the masticatory system. The biologic processes and local environmental factors are in balance. The stresses acting on the teeth are dissipated normally with a balance existing between the stresses and the adaptive capacity of the supporting tissues, masticatory muscles, and TM joints. This type of occlusion is typically found in the healthy, comfortable patient who does not require dental treatment even if the occlusion itself does not present morphologically as a theoretical ideal occlusion. A physiologic occlusion can present as a number of disparate structural variations but, in a given individual, represents an acceptable functional occlusal relationship.

To maintain a physiologic equilibrium, the masticatory tissues continually adapt throughout life to various internal biologic factors and external environmental factors as well as time-dependent changes. Physiologic variations in dental and skeletal relationships typically occur slowly, over time, during growth or as acquired variations that have had sufficient time to allow for tissue adaptation. The fibrous connective tissues and underlying mesenchymal layers of the TMJ are particularly capable of adaptation by continual progressive and regressive remodeling.[6] Studies have shown strong evidence that the potential for tissue repair following insults is much greater for the TMJ than other synovial joints whose articular surfaces are composed of hyaline cartilage (**Figure 1**).[7,8] Also, the natural capacity for muscle adaptation allows for changes in muscle tone, in the number of sarcomeres, in connective tissue apposition at the muscle-tendon interface, in the muscle fiber direction, and in the migration of muscle insertions.9 At the occlusoradicular level, slight to moderate tooth wear (age dependent), limited physiologic mobility, and even minor tooth repositioning are forms of adaptation (**Figure 2**).

Inappropriately, the term "malocclusion" is used sometimes to imply a nonphysiologic occlusion and/or a need for occlusal treatment. Malocclusion implies that the occurrence of occlusal variation is in itself disease. But many so-called malocclusions are essentially morphologic variations that are judged against normative population means.10 It has been estimated that approximately 95 percent of the population has some form of a malocclusion, i.e., crowding, malalignment, or structural abnormality.11 In fact, a developmental morphologic variation without evidence of tissue pathology is actually a physiologic adaptation to a combination of intrinsic and extrinsic factors. The resulting functional equilibrium that ensues becomes the most physiologic relationship for that particular individual.

Occlusion is not and should not be defined by rigid, stereotyped structural ideal relationships that are theoretically required for optimum health, function, and comfort. It is quite evident that the tissues of the masticatory system are extremely capable of adapting to their environment, and extreme caution and care must be taken before this functional equilibrium is clinically altered. On the other hand, if the equilibrium shifts toward a nonphysiologic state due to loss of function from adverse loading including parafunction, by a loss of the capacity to adapt, or from disease, then

Figure 1. The different zones of cell populations covering the surface of the mandibular condyle as opposed to other synovial joints, which are covered by hyaline cartilage.

Figure 2. A list of possible mechanisms that allow for muscle adaptation.

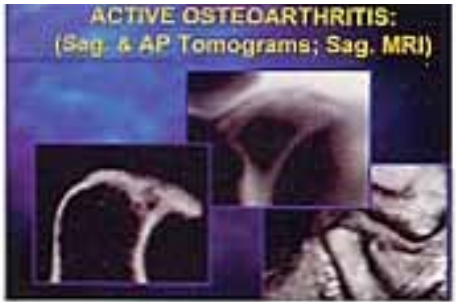

Figure 3. From left to right, sagittal and anterior-posterior tomograms and sagittal magnetic resonance image of active osteoarthritis in the TMJ resulting in possible sudden changes (supracontact) in the posterior occlusion on the same side.

Figure 4. Panoramic view of a fractured right condyle resulting in a sudden, abrupt change in the occlusion.

Figure 5. Working casts mounted in centric relation on an articulator during the laboratory sequence to facilitate returning the restorations to the patient's mouth in the treatment room using a reliable reference position.

Figure 6. Restorations placed in the mouth aided by the centric relation reference position of the mandible (condyle) to the cranium.

the occlusal category could change to a nonphysiologic occlusion.

Nonphysiologic Occlusion

A nonphysiologic occlusion is defined as an occlusion in which the tissues of the masticatory system have lost their functional equilibrium or hemostasis in response to the functional demand, injury, or disease. The masticatory tissues are biologically distressed and unable to adapt to the environmental factors acting on the system and/or the functional demand exceeds the adaptive capacity of the system. Pathologic changes can result from sudden or abrupt insults or from loading of sufficient magnitude or duration that there is insufficient opportunity for tissue adaptation. These sudden, disruptive changes can be caused by trauma including parafunction, inflammation, or disease and, at times, from iatrogenic causes[12] (**Figure 3** and **Figure 4**). Tissue systems begin to fail and unless the direction of the functional equilibrium repairs itself, treatment is usually required. Based on tissue damage, pathology or dysfunction, the occlusion would be categorized as a nonphysiologic occlusion.

A nonphysiologic occlusion is directly related to dental health, or lack thereof, but not to musculoskeletal jaw disorders (TMD). Dental signs and symptoms related to a nonphysiologic occlusion include an uncomfortable, uneven, or "lost" bite; sensitive, painful, or sore teeth; worn, cracked, or broken restorations, teeth, roots, or implants; and abnormal tooth mobility, widened periodontal ligament, fremitus, tooth migration, and occlusion-related periodontal pain. However, occlusion has not been proven to be directly correlated to musculoskeletal conditions affecting the jaw (TMD) except for a weak association with a unilateral lingual cross-bite in children and those with five or more missing posterior teeth.[13] But, the studies associating loss of posterior support and TMJ degenerative changes reported that bruxism is a necessary additional contributing factor.[14,15] Also, the studies relating missing posterior teeth and articular degeneration did not address the confounding factor of age, making the association suspect.

To date, clinical studies have shown a negative association between dental attrition or parafunction and jaw disorders. Nor does the type of guidance contact (working, anterior, or canine guidance contacts) or working or nonworking contacts in laterotrusive jaw

movements have any association with jaw disorders.[16] There is an association between occlusal variations of sufficient magnitude and musculoskeletal jaw disorders, but it is not typically a causal one. The associated significant occlusal variations are a severe skeletal anterior open bite (overjet greater than 6 to 7 mm). and a discrepancy of greater than 2 mm between the centric relation or retruded contact position and the intercuspal position.[17] However, it is important to point out that association does not prove cause and effect; and, in fact, open bite and asymmetrical retruded contact position-intercuspal position (RCP-ICP) discrepancies are usually the effect of jaw disorders rather than the cause.[18]

Treatment Occlusion

Treatment of the occlusion should be considered on an individual basis based on the specific physiologic needs of the various tissue systems within the masticatory system rather than a preconceived, stereotyped concept. Treatment of the occlusion includes occlusal adjustment of a single tooth to a full-mouth adjustment or equilibrium, restorative therapy with a single restoration to a full-mouth rehabilitation, prosthodontic therapy including implant dentistry, and/or orthodontic therapy including orthognathic surgery. In general, the goals are the same for all treatment approaches: Restore anatomical form by restoring or replacing missing structure; establish structural stability by optimizing the force distribution; and provide functional harmony for mastication, deglutition, and speech. The rationale for treatment is to improve dental health, function, comfort, and esthetics.

Occlusal treatment is indicated for the following dental conditions: pulpal and periodontal sensitivity; progressive tooth mobility and/or lack of stability (i.e., lack of proximal contacts, tooth extrusion or migration); poor alignment, crowding, or rotations of the teeth; structural damage to the teeth (i.e., tooth fracture, chipping, abnormal wear, root resorption, and possibly abfraction); pericementitis, widened periodontal ligament, or related periodontal destruction; missing teeth; impaired masticatory function (i.e., mastication, swallowing, speech); and esthetic considerations.[19] Occlusal treatment is not indicated when there are concurrent problematic general or dental health conditions. If there is a lack of physical or emotional stability, lack of maxillomandibular or dental stability, or lack of interest, concern or compliance by the patient, occlusal treatment should not be instituted. Lastly, when there are complaints of pain including chronic pain syndromes, e.g., fibromyalgia, systemic pain, orofacial pain or dental pain, occlusal treatment is not indicated. Unfortunately, many theoretical, ideal occlusal treatment plans are stereotyped and are the same for every patient regardless of the diagnosis. The predetermined occlusal scheme is fabricated to treat all patients regardless of their functional needs or dental diagnoses. To superimpose the clinician's concept of an ideal structural and/or functional relationship on a particular patient is inappropriate.

Treatment Category

To plan the proper occlusal treatment required for a specific set of conditions, diagnostic decisions must be made first. The diagnostic decisions are based on the type and extent of treatment that needs to be performed; namely, whether to maintain, modify or re-establish the existing occlusal schema.[20] The three different treatment categories are determined by clinical judgment and are based on the individual structural and functional demands of the patient. Also consideration should be given to the clinician's training, skill, and experience as well as the patient's health, interests, and abilities when establishing the specific treatment category.

The decision to maintain the existing occlusion is based on the clinical findings that a functional equilibrium between the tissue systems has been established; and, thus, the resulting acceptable occlusion should be maintained. The intra- and interarch tooth relations, the intercuspal position (maximum intercuspation or centric occlusion), and the vertical dimension of the occlusion are acceptable. Great care should be exercised to maintain an acceptable functional equilibrium before changing it to meet some idealized theoretical concept. If a clinical decision is made to modify or re-establish the occlusion, there should be definite and substantial reasons to support the decision. Indeed, a modification classification is predicated on the fact that there needs to be some modification of the intra- and/or interarch relations, but not of the existing intercuspal position or vertical dimension of occlusion. They are deemed acceptable and, therefore, should be maintained. Whereas a re-establishment category is determined by the fact that there is not only a clinical need to re-establish or reorganize the intra-interarch relations but that the intercuspal position and/or the vertical dimension of the occlusion needs to be re-established as well.

Once the treatment classification has been determined, treatment planning and sequencing must be considered. Maintenance dentistry requires very little planning in that a limited number of restorations is simply introduced

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to an established, acceptable occlusal scheme. Whereas, the modification classification requires slight to moderate change or improvement, such as minor occlusal adjustment, tooth movement, or opposing tooth restoration or replacement, prior to accepting the original acceptable occlusal scheme. However, the re-establishment classification usually requires major changes to a clinically unacceptable occlusal scheme primarily associated with the need to establish a new intercuspal position and/or vertical dimension of the occlusion.

There are specific and rather precise technical requirements and clinical considerations involved when an occlusion scheme has to be re-established or reorganized. The newly re-established occlusal scheme does not benefit from time-related adaptation but, rather, must be integrated with and conform to the remaining tissues of the masticatory system. The jaw relationship must be stabilized and painful or pathological conditions treated prior to definitive occlusal therapy.[21] This requires careful attention to detail and proper treatment sequencing including possible pretreatment with an interocclusal appliance; prior ancillary treatment, i.e., endodontic, periodontic, or surgical treatment and, at times, prolonged provisional treatment. Lastly, and very importantly, when re-establishing the occlusal scheme, a treatment reference position must be established. During maintenance and modification treatment, the reference position has, by definition, already been established by virtue of the fact that the intercuspal position and vertical dimension of the occlusion have been deemed acceptable and only need to be maintained. But when the intercuspal position and/or vertical dimension needs to be re-established, a new, reproducible reference position is required because, by definition, the original intercuspal position is no longer available or acceptable, e.g., orthodontic, orthognathic, complex restorative, or prosthetic/implant treatment (**Figures 5 and 6**).

Reference Positions

There are, in general, three jaw relations that are used clinically as reference positions: the intercuspal position (ICP), myocentric (MC) and centric relation (CR), or the retruded contact position (RCP).[1] The intercuspal position is clinically the most reproducible reference position. It is determined morphologically by the shape and location of the teeth, by the periodontal sense organs through proprioception, and by muscle memory, which is reinforced by tooth contact. The sensory input allows the mandible to open and close rapidly and repeatably in the same position. When ICP is unacceptable, there are two alternative clinical approaches to establish a reproducible reference position. Either a joint-ligamentous dictated position, CR or RCP, or a muscle-dictated position, MC, can be used reliably to relate the mandible to the cranium on a relative reproducible basis. Variations of a muscle-dictated jaw relationship determination using either tongue, speech, or rest position, or voluntary repeated mandibular closures are reported in the clinical literature but are not easily standardized and, therefore, will not be presented.

Myocentric

The MC reference position is obtained through the use of transcutaneous electrical neural stimulation creating a neuromuscularly oriented occlusal position.[22] The theory is that the stimulation from surface electrodes placed over the sigmoid or mandibular notch stimulates the motor root of the trigeminal nerve and the facial nerve with an "all or none" motor response and is, therefore, reproducible. Studies suggest that the stimulation acts only in the periphery without the participation of the central nervous system as reported by the manufacturer.[23] Nonetheless, clinicians have developed techniques with the use of electrical stimulation of the facial and some masticatory muscles that by their report provide a reproducible and acceptable mandibular position. This approach must account for variations in muscle tone throughout the day with changes in activities of daily living, various emotional states, posture, and fatigue.

Centric Relation

The definition of centric relation keeps changing in the literature. Conceptual approaches to the definition of centric relation can be anatomic, orthopedic, or operational. The anatomical definition is the traditional dental concept of the optimum structural relationship of the mandible to the cranium. One of the seven anatomical definitions published in the seventh edition of the "Glossary of Prosthodontic Terms" is as follows: "The maxillomandibular relationship in which the condyles articulate with the thinnest articular portion of their respective discs in the anterior-superior position against the posterior slope of the articular eminentia."[24] The orthopedic definition is based on the physical medicine concept of a closed-pack relationship of articular structures as determined by function. The condyle would be "seated" in the fossa with an interposed articular disk, if not compromised, as determined by the mandibular muscles during function, i.e., the compression or functional

Figure 7. Treatment objectives.

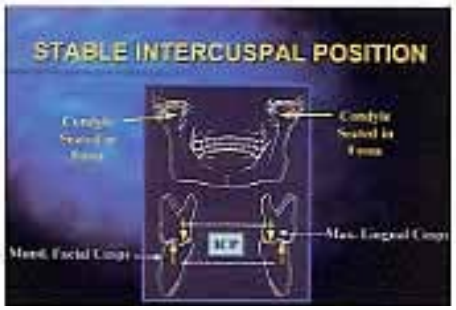

Figure 8. Stable intercuspal position of the condyles within the fossae and cusp fossae contacts of the opposing teeth.

Figure 9. Centric stops allowing occlusal loading forces to be directed axially.

Figure 10. Placement of a shim in the anterior tooth region results in the condyle becoming more seated superiorly or in the most posterior tooth region results in a possible distraction of the condyle.

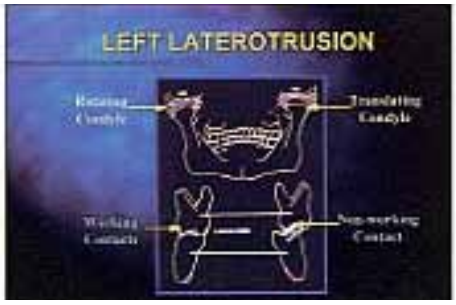

Figure 11. Left mandibular laterotrusion resulting in rotation of the left condyle and translation of the right condyle and working guidance contacts on the left teeth and nonworking contacts on the right side. Note: If tooth contacts are not deflective, the contacts by themselves are not detrimental to smooth gliding movements of the mandible.

Figure 12. Excursive pathways during working, nonworking, and protrusive mandibular movements allowing for smooth gliding movements of the mandible.

loading of the articular structures during chewing and swallowing. The closed-pack relationship of articular structures in any joint is considered to be both physiological and biomechanically stable. Because tomographic surveys of nonsymptomatic subjects have shown great variation in condylar position, this functional definition may be more accurate than the first one, which is based on anatomical relationships that cannot be validated. The third and more operational definition is based on the concept that in order to perform precise, complex occlusal treatment, it is technically advantageous to use a reproducible border position of the jaw.1

CR or RCP is independent of tooth contact and is determined by manipulation of the mandible in a rotary movement about a transverse horizontal axis.[25] The operational significance of CR is that it allows the clinician to evaluate the progress and outcome of the treatment based on a definite starting and ending point. One clinical advantage of the hinge axis is that technically the patient's horizontal axis of closure can be transferred to an articulator allowing for the possibility of alterations, within limits, of the vertical dimension of occlusion. The mandible is manipulated in a retruded direction while being supported in a superior direction at the gonial angles to allow the condyles to be braced in the most anterio-superior direction against the posterior slopes of the eminentia.[26] Techniques must be altered after condylar fracture, bony degeneration, and soft tissue alterations because the structural components that originally provided for a physiologic position of the condyle are no longer available. The patient may have to be in a more upright position with gentle manipulation directed more superiorly than posteriorly and with the patient aiding the closure. Thus, technique and experience become critical, but it has been shown that this approach can become clinically replicated.[27]

Specific Treatment Objectives

Once the treatment category has been determined, specific clinical objectives need to be established to develop optimum dental health (**Figure 7**). The specific objectives that are suggested from a optimum functional standpoint include:

- Maximum symmetrical distribution of the centric contacts in the intercuspal position (which may be in CR, depending on the treatment category);
- Axial or near axial loading of the teeth;
- An acceptable occlusal plane;
- Guidance contacts allowing for

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freedom without deflection in closing and excursive gliding mandibular movements; and
- An acceptable vertical dimension of occlusion and interocclusal resting range.[1]

Even distribution of tooth contacts in the intercuspal position is desirable to establish maximum stability and optimum distribution of the closing forces (**Figure 8**). The natural number of ICP contacts averages approximately seven bilateral contacts, with the molars loaded more than the premolars, which are loaded more than the cuspids.[28] If the location of the occlusal load occurs only in the most distal molar region, specifically the third molar and possibly in the second molar region, it may act as a deflective contact causing the ipsilateral condyle to become unloaded (distracted) with the contralateral condyle undergoing increased compression (**Figure 9x**).[29]

Axial loading of the teeth (**Figure 10x**) in a slight mesial direction allows the reaction forces on closure or during clenching to be transmitted vertically rather than laterally along or near to the long axes of the teeth. Vertical loading forces are better accepted by the viscoelastic periodontal ligament than horizontal forces.[30] Nonaxial loading generates mechanical moments or torquing forces at or near the alveolar crest of supporting bone. Axial loading of dental implants is even more critical because of decreased proprioceptive input as a consequence of investing bone rather than the periodontal ligament.[31]

The plane of occlusion is defined as the average imaginary plane established by the incisal and occlusal surfaces of the teeth.[2] Because of the compensating anteroposterior and mediolateral curvatures of the teeth, the plane of occlusion is actually curvilinear. The angulation of the occlusal plane is on the average approximately 10 degrees higher or steeper than the Frankfort plane. The importance of these occlusal planes is their influence on cusp height and position and their relationship to tissues in the masticatory system.

Functional harmony is improved by providing unrestricted smooth gliding movements of the mandible. Excursive guidance contacts can be provided by one or more teeth, e.g., canine guidance, anterior guidance, or group-working guidance. There appears to be no scientific evidence to support one occlusal scheme over the other,[13] and a wide variety of contacts are found naturally. Functional harmony requires that tooth contact during mandibular movements be guiding ones as opposed to deflective contacts (**Figure 11**). Deflective contacts, also called premature or interceptive contacts, are defined as occlusal contacts that divert the mandible from a normal path of closure or interfere with normal, smooth, gliding mandibular movement and/or deflect the position of the condyle, teeth (analogues), or prostheses (**Figure 12**).

The vertical dimension of the occlusion is defined as the distance between two anatomical points, e.g., on the face or jaws, when the occluding members (teeth, bite blocks) are in contact.[2] The postural resting range usually is a 1 to 3 mm open position of the mandible relative to ICP. General body, head and neck posture, speech, sleep, age, stress, and pain all influence the postural resting range. Clinical rest position is not a position of minimal muscle activity but rather an upright postural position.[32] Patient accommodation to significant changes in vertical dimension of the occlusion suggests that it is not immutable but can be modified within reason without clinical consequence.[33]

Conclusion

In the past, the dental literature in the field of occlusion was primarily based on clinical observations, case reports, and testimonials. Technical bias drove treatment rather than scientific knowledge in many cases. However, today there is a definite momentum within the dental profession to move from a clinically based position to an evidenced-based position in the field of occlusion. The scientific literature's questioning of the association between occlusion and musculoskeletal jaw disorders does not invalidate the well-established association between occlusion and dental health.[34] However, it is difficult to prove cause and effect between the relationship of occlusion and the health of the masticatory system due to the lack of scientifically established criteria for an optimum treatment occlusion. Also, there still is a lack of knowledge regarding the natural history of the various occlusal relationships; and the large number of possible contributing factors make the confounding factors extremely difficult to control in clinical trials.

The same requirements for proper occlusal therapy are as valid today as in the past. Because implants do not have a forgiving periodontal ligament with special protective senses, the need for more precise occlusal treatment becomes even more critical. Until more evidence is established, treatment of the occlusion should be individualized to meet the patient's needs based on today's evidence and not on a clinician's belief system of an optimum structural relationship for its own sake. Treatment of the occlusion should only be considered when there are clinical signs and/or symptoms within the masticatory system that can be definitively related to the dysfunctional and pathological conditions

of the various tissue systems. Treatment plans need to be modified based on the patient's abilities, desires, compliance, health, and emotional status in addition to the clinician's abilities, training, and experience. The cardinal rule should be to proceed carefully with treatment of the occlusion using the least invasive procedure as much as possible with all the skill and expertise possible. Treatment of the occlusion is essential to, and a requirement for, appropriate professional dental care; it is rarely essential to, or a requirement for, the management of musculoskeletal disorders affecting the jaw (TMD).

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Occlusal Considerations in Determining Treatment Prognosis

Richard T. Kao, DDS, PhD; Raymond Chu, DDS; and Donald A. Curtis, DMD

ABSTRACT To function in occlusal harmony, the masticatory apparatus -- composed of the teeth and its supporting structures, temporomandibular joints, and associated neuromusculoskeletal structures -- must operate in an integrated and dynamic manner. Loss of integrated function, or of homeostasis in response to functional demand, may generate problems in occlusion. In health, adaptive changes occur with the teeth and periodontium in response to functional occlusal forces. With periodontal and endodontic disease, this adaptive capacity diminishes. The ability to foresee how these changes may influence dental treatment is important in the art of determining treatment prognosis.

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Prognosis is the prediction or forecasting of the probable course and outcome of a disease. In clinical dentistry, the definition of prognosis has been extended to include the probable outcome that can be achieved with treatment. With clinical experience, the mechanics of dental procedure become less challenging. Rather, the ability to appropriately diagnose the condition and determine which procedure will provide the optimal outcome is the more difficult task. Unlike clinical procedures, which are technique-oriented, the art of determining prognosis is based on each individual's collective learned and clinical experiences. Due to the variety of past experiences, views of treatment prognosis may vary.

Numerous factors influence dental prognosis (**Table 1**). These determinants can influence either or both the prognosis of individual teeth and overall treatment prognosis. Whereas the prognosis of the individual teeth will define which teeth are available for incorporating into the various treatment plan, the overall treatment prognosis will define whether a treatment should be undertaken, which of the available teeth conforms to the treatment, and whether it is likely to be successful.

This review paper will describe how occlusion influences the prognosis of the individual teeth and, subsequently, the overall treatment prognosis. Occlusal harmony exists when the various components of the masticatory system are healthy and can withstand the functional stress (**Figure 1**). When the tooth is affected by periodontal and endodontic diseases, the tooth becomes weakened. Despite therapy,

the adaptive capacity of the tooth has been compromised, which changes the prognosis of the tooth. This paper will review how these occlusal variables influence prognosis.

Factors that Influence Functional Demand

Intensity of Occlusal Forces

Classically, occlusal forces are evaluated based on local factors such as periodontal health, surface area of periodontal support, clinical crown height, and the contact angle to the opposing dentition. Also important is the number of posterior tooth-to-tooth stops, which distribute the occlusal force. New insights have come from computer modeling and orthodontic studies that indicate that other variables can also be significant. Musculoskeletal factors can influence the forces placed on the dentition. Profit1 has shown that an individual with a high Frankfort mandibular plane angle will generate about half of the first molar occlusal forces as an individual with a low angle. Additionally, Hannam and Wood[2] have shown the first molar occlusal force to be strongly influenced by the cross-sectional area of the masseter muscle. The masseter is readily evaluated clinically and accounts for 66 percent of the occlusal forces the patient is capable of generating. The role of these musculoskeletal factors on the occlusion of teeth as opposed to dental implants has been reviewed in detail by Curtis and colleagues ("Occlusal Considerations for Implant Restorations in the Partially Edentulous Patient," in this issue). Though these occlusal factors cannot be altered, the clinician must learn to appreciate their significance in determining prognosis.

During normal occlusal activities, occlusal contact and wear are minimal, occurring briefly during chewing and swallowing. With the presence of parafunctional habits such as clenching and bruxism, occlusal forces can become extensive. Trenouth[3] showed that in subjects with bruxism, total occlusal contact time (38.7 minutes) was approximately seven times longer than in control subjects (5.4 minutes). With longer periods of occlusal contact, there is an increase in frequency and the total amount of occlusal force. Some have postulated that this increases stress on the periodontium. This idea, however, is not supported by clinical studies. Shefter and McFall,[4] in a clinical survey of 66 adults, studied the occlusal relation as it relates to periodontal status. Collected data included dental histories, periodontal analysis, analysis of malocclusion, centric discrepancies, patterns of excursive movements, and patterns of occlusal contact and wear. Periodontal analysis indicates that occlusal factors play a minimal role in the progression of periodontal disease in healthy dentitions. An issue not addressed is the effect that parafunctional habits may have on unhealthy dentition, i.e., periodontally involved teeth with mobility. The difficulty in addressing this question scientifically is that mobile teeth are difficult to manage; the quantifying of mobility is controversial; and increases in mobility may be caused by multiple factors, including failing periodontium, increased occlusal trauma, parafunctional habits, extent of functional load, and existing dentition present to provide protection from occlusal load. Finding an answer to this question is complicated by the fact that it would require a prospective study allowing a harmful destructive habit to persist. The need for control and the ethical issues involved are such that this type of study can never be undertaken. For practicing clinicians, the solution is one of eliminating as many etiologic variables as possible to achieve the best possible prognosis. Thus, if parafunctional habits exist, they should be managed.

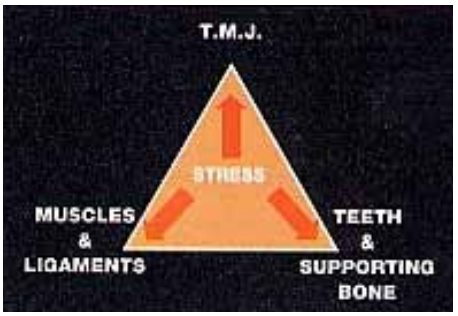

Figure 1. Occlusal harmony is dependent on each components of the masticatory system to withstand functional occlusal demand.

Age

In determining the overall treatment prognosis, age is perhaps the most important determinant. A treatment is a success if it is functional and survives the life span of the patient. A prognosis for a treatment plan may be fair for a patient 70 years of age (if the anticipated life span is 95 years old), but have a more dismal outlook for a patient 30 years of age. This is often seen in cases where a 30-year-old patient with 5 to 6 mm of attachment loss may require more aggressive treatment than a patient 70 years of age. Likewise, in a young patient, delaying the fully edentulous state through the use of a partial denture or an implant-supported prosthesis is preferable because the fourth or fifth set of full dentures will not be functionally ideal. Similarly, in medicine, the orthopedic surgeon will try every means to avoid placing hip implants in patient until he or she is well over 50. This is due to the limitation in the number of successful hip implants that can be placed. With technological advances, osseointegration has improved the situation in the partially dentate patient as well as patients requiring hip implants. So as technological improves, these limitations decrease and the prognosis

Table 1.
Factors Influencing Prognosis

The prognosis of individual teeth
- Mobility
- Attachment level and relative bone support
- Periodontal pockets
- Tooth and root morphology
- Infrabony defects
- Furcation involvement
- Relationship to adjacent teeth and edentulous area
- Tooth vitality and endodontic status
- Extent of restoration present
- Caries and root resorption

The overall prognosis
- Age
- Medical and systemic background
- Patient compliance
- Individual tooth prognosis
- Strategic position and pulpal status of remaining teeth
- Present periodontal status (height of bone, attachment level, mobility, inflammation)
- Assessment of past periodontal response to disease
- Estimation of present level of disease of activity
- Occlusion, malocclusion, and anatomical determinants of occlusal force
- Number of remaining teeth

improves. This notion of considering age in the overall treatment prognosis needs to be a more consistent theme in patient evaluation.

Age also plays an important role in the prognosis of individual teeth. With age, the signs of attrition and abrasion result in loss of tooth structures, crazing, and an increased presence of fracture lines (**Figure 2**). The limitation of restorations becomes more apparent over time as amalgam expands, corrodes, and fractures or as the composite seal is lost due to the differential expansion coefficient and restorative wear. All of these events will dictate replacement and additional removal of tooth structure as the restoration gets larger. This weakens the tooth structure to functional occlusal load so the probability of tooth fracture is increased. With tooth fracture, there may be the need for root canal therapy, a post-core, and a crown. The subsequent failure of this endodontically treated tooth may result in extraction and replacement with a bridge. Due to the harsh environment of the oral cavity, there tends to be a need to replace existing restorations. Thus the age of the patient and the characteristics of the existing restorations may influence the prognosis of the tooth and subsequently the prognosis of the overall case.

Age may also influence individual tooth prognosis. Traditionally, increased incidence of attachment loss and gingival recession correlate with increasing age. An excellent review5 on the epidemiology of periodontal disease among older adults indicates that moderate levels of attachment loss, bone loss, and recession are found in a high percentage of elderly adults, especially minorities. When one examines the various epidemiological studies closely, one finds that the rate and pattern of disease was similar to other adult populations. Being older does not increase the risk nor incidence, nor change the episodic pattern of periodontal disease. The amount of periodontal disease is still based on individual risk factor and oral hygiene. And as people get older, the accumulation of destructive events as the consequence of disease activity and poor oral hygiene become more evident. The amount of accumulated periodontal disease in relation to the patient's age should be factored into the prognosis.

Role of Pulpal Health in Response to Occlusal Force

Although healthy teeth can withstand normal occlusal force, nonvital and/or endodontically treated teeth have an increased potential for root fracture (**Figure 3**). Based on the research of Helfer and colleagues,[6] many dentists assume that endodontically treated teeth are weakened and fracture-prone because of the desiccation of the tooth structure. This is not the case since photoelastic study indicates that there is little difference in fracture resistance between vital and nonvital teeth. This section will review findings that suggest that increased susceptibility to fracture is associated with the role of the endodontically treated tooth in the restorative design and the amount of tooth structure removed.

Several classical studies have examined the relative amount of stress placed on a tooth based on its role in a prosthetic design. Teeth that serve as fixed prosthetic abutments bear greater stresses in function than a single crown.[7-8] When teeth are used as a removable partial abutment, the amount of stress increases.[9-10] It further increases when a tooth serves as the distal abutment tooth in a distal-extension partial denture design.[11-14] These stresses can fracture teeth weakened by endodontic therapy and dowel space preparation.

A selected review of retrospective chart review studies confirms the increased rate of fracture failure in endodontically treated teeth. In a review of 6,000 patient records by Sorensen and Martinoff,[15] root fracture was shown to be up to five times more frequent in endodontically treated teeth than in healthy teeth. Further analysis indicated that the failure rate of endodontically treated teeth in removable partial dentures (22.6 percent) was twice that of those in fixed prostheses (10.2 percent) and four times that of teeth with crowns (5.2 percent). The incidence of root fracture increases with age and occurs more frequently in posterior dentition.[16] Resistance to fracture increases when more tooth structure is available.[17] In a longitudinal five- to eight-year review of 299

patients who were treated for periodontal-prosthetic therapy, Nyman and Lindhe[18] noted that 75 percent of the abutment teeth that fractured were endodontically treated and serving as terminal abutments.

The main risk factor of root fracture is the loss of dentin during endodontic treatment. Excessive removal of dentin during access preparation, canal fill, and post preparation weakens the tooth and makes it prone to fracture.[19-20] Therefore, it is important to minimize dentin removal and post preparation. Since the placement of a post does not reduce nor improve the distribution of occlusal forces,[21-22] the use of posts should be limited to situations where they are required to provide retention for a core.[23] To achieve optimal fracture resistance of crowns on endodontically treated teeth, Ketac-Silver cores have been shown to be superior to amalgam or bonded amalgam.[24] Lastly, having at least 2 mm of crown margin apical to a core buildup is important for retention and resistance to occlusal forces.[19,25]

These studies indicate the pulpal status of the tooth and its relationship to the amount of occlusal stress may significantly influence its prognosis. An endodontically treated tooth may have a fair prognosis in a fully dentate occlusion, but the same tooth may have a guarded prognosis in a partially dentate dentition. Furthermore, when this same tooth is the distal abutment in a long leverage free-distal extensional partial denture design, the prognosis is poor. This is an example of how an individual tooth may have a fair/guarded prognosis but because of the overall treatment plan, the prognosis may be significantly worse. In fact, the treatment plan may even dictate a poor/hopeless prognosis and result in strategic extraction or the use of implant-supported prosthesis.

Role of Periodontal Health in Response to Occlusal Force

Occlusion in Healthy Teeth vs. Periodontally Involved Teeth

In evaluating the prognosis of individual teeth to occlusal forces, an important determinant is the health of the periodontium. This relationship, termed "occlusal trauma,"[26-27] describes the pathologic alterations or adaptive changes in the periodontium in response to occlusal forces. Other terms used in the literature include "trauma from occlusion," "traumatizing occlusion," and "occlusal overload." The interrelationship of occlusion and periodontal disease has been recently reviewed.[28]

Occlusal trauma can be classified as either primary or secondary.[26] Primary occlusal trauma is the effect of excessive or abnormal forces acting on a normal and healthy periodontium. Secondary occlusal trauma refers to the effect of normal or excessive forces acting on a reduced periodontium. While the literature and many textbooks emphasize this distinction, it is of little clinical relevance since the consequences of trauma from occlusion are similar and independent of the height of the periodontium. The more important fact is that occlusal trauma is dependent on how well the periodontium can withstand and distribute the occlusal forces. With a reduced periodontium, it takes a comparatively small force to cause occlusal trauma that will result in either adaptive or pathologic compensatory changes.

Clinical Diagnosis of Occlusal Trauma and Its Therapeutic Implications

The major clinical findings in patients with occlusal trauma include the presence of tooth mobility, fremitus, and pain from damaged supporting tissue when in the presence of excessive occlusal forces. Though clinical and radiographic signs such as widening of the periodontal ligament space, angular bony defects, abnormal occlusal contacts, infrabony pockets, crestal funneling, cervical notching, furcation rarefaction, vertical bone loss, hypercementosis, condensation of trabecular bone, and gingival recession are frequently associated with occlusal trauma, the clinician must remember their presence is only suggestive but not pathognomonic of occlusal trauma.[3,29-32] Many of these changes can be produced by a variety of other factors.

Increasing tooth mobility is the hallmark of occlusal traumatism. Mobility, per se, is a reflection of past and present disease experience and/or adaptive changes of a tooth and describes the ability of the tooth to withstand occlusal forces. This ability is highly influenced by past pathologic conditions resulting in attachment loss, the height of the remaining alveolar bone, and root morphology. These factors, added together, give the crown-to-root ratio, which dictates the mechanical resistance of the tooth to an applied force. Though many clinicians emphasize the importance of fremitus, it is not indicative of occlusal trauma. Fremitus is simply a functionally induced form of mobility that is reflective of past and present disease and/or adaptive changes. The clinical dilemma is to decide if the tooth movement observed is reflective of a past or ongoing pathologic condition.

Determining detrimental change involves observation of increasing tooth mobility over time. Unfortunately, this is a clinically difficult task. It would require multiple visits and a sensitive mobility-monitoring mechanism that can only be provided with a periodontometer or a Periotest (Siemens). This is not clinically practical due to the time requirement

Figure 2. With periodontal and endodontic health, heavy occlusal stress is compensated with crazing, increase fracture lines, and attrition. This may lead to the loss of vertical dimension. To withstand this type of constant occlusal stress, the compensatory requirement is good periodontal and endodontic health.

Figure 3A. A patient with signs of heavy attrition (photo courtesy of Dr. R. Gurrola).

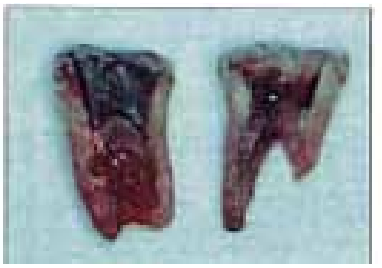

Figure 3B. The heavy attrition shown in Figure 3A led to the fracture of this endodontically treated tooth (photo provided by Dr. R. Gurrola).

Figure 4. A history of increasing tooth mobility should be investigated when there are signs of increase in diastema spacing, shifting of teeth, and change in occlusion.

Figure 5A. With the re-establishment of periodontal health, cross-arch splinting can be successful as demonstrated in this case. Pre-treatment photo.

Figure 5B. Extraction of hopeless teeth and re-establishment of periodontal health.

Figure 5C. Coping placement for the abutment teeth.

Figure 5D. The placement of a splinted cross-arch prosthesis.

Figure 6A. With implant-supported prosthesis, biomechanical distribution of occlusal forces can be better distributed as exemplified in this case. Pretreatment photo.

Figure 6B. Removal of hopeless teeth and periodontal treatment.

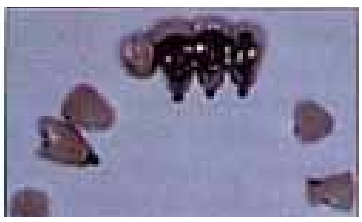

Figure 6C. Four implants were placed in the Nos. 5, 8, 9, and 10 positions so biomechanical forces can be distributed. The prosthesis is also segmented into six pieces so repairs and obsolescence can be accommodated.

Figure 6D. Radiographs of the final prosthesis.

and the lack of sensitivity associated with most clinically used mobility indices. Operationally, the diagnosis of increasing mobility is made based on patient history of changes in tooth positions, increase in diastema, movement and shifting of teeth, and change in occlusion (**Figure 4**). This is followed by an occlusal analysis of the resulting changes and existing mobility pattern. From this information, one can diagnose presumptive situations of occlusal trauma. Due to the presumptive nature of the diagnosis, treatment and outcome analysis needs to be performed over time. In extensive restorative cases, evaluation of tooth mobility and suitability as abutment teeth may require long-term provisionalization of the prosthodontic case.

Several factors can influence tooth mobility. Mobility has been shown to influence clinical prognosis. If mobility is deemed clinically significant in treatment outcome, there are several strategies to decrease mobility.

The Influence of Mobility on Therapeutic Prognosis

The clinical implication of tooth mobility and increasing tooth mobility has been the focus of several recent studies. Rosling and colleagues[33] investigated the importance of mobility in patients with advanced periodontal disease. These patients were treated by open flap curettage and placed on supportive periodontal therapy. It was found that mobile and nonmobile teeth responded equally well to periodontal therapy. The maintenance and survival rates for treated mobile teeth were similar to those of nonmobile teeth as long as the patient complied with a rigorous two-week recall schedule during the supportive periodontal therapy phase. This study suggests mobility has no long-term detrimental effect as long as good oral hygiene is maintained. The problem with this study is that the compliance and frequency of maintenance visits required are not practical.

Investigators at the University of Michigan have published a series of studies addressing this issue with more realistic clinical conditions. The initial report by Fleszar and colleagues[34] focused on a subpopulation of patients in the University of Michigan longitudinal study on periodontal response to therapy that included 72 patients who had undergone periodontal therapy and completed at least one year of recall. These cases were followed for four additional years. At the end of that period, the investigators concluded that periodontal pockets associated with mobile teeth do not respond as favorably to treatment as compared to nonmobile teeth. Furthermore, there was attachment loss that occurred during the first two years following surgical therapy. These conclusions were confirmed in another subpopulation of the University of Michigan study by Wang and colleagues.[35] In examining 24 patients, they found that molar teeth exhibiting mobility at baseline or during the first year of treatment had more attachment loss at the end of eight years than molars without mobility. These findings are consistent with findings by Wagner,[36] which demonstrated that initial mobility, gingivitis, and mean probing depth together were significant risk factors for predicting future attachment level changes following periodontal treatment. Epidemiological data obtained by Ismail and colleagues[36] confirmed that the presence of tooth mobility was a significant risk factor for future attachment loss. These studies suggest tooth mobility, especially when unmanaged, will increase the risk of attachment loss.

Clinical Management of Occlusal Trauma and Tooth Mobility

Since occlusal trauma may result from two concurrent etiologic factors – excessive occlusal force and inflammatory periodontal disease – each problem is treated separately. Occlusal therapy is generally addressed following, or in conjunction with, periodontal therapy. Controlling or decreasing tooth mobility is the clinical measure for therapeutic success. The sequence for clinical management of occlusal trauma consists of three basic strategies: the re-establishment of periodontal health, occlusal adjustment, and dental splint therapy.

Re-establishment of Periodontal Health

Tooth mobility associated with periodontally diseased tissue can be decreased with periodontal therapy. Measurements with Muhlemann's periodontometer have demonstrated an average decrease of mobility by 20 percent within four months after plaque and calculus removal.[38] Goldberg[39] found a 25 percent decrease in mobility shortly after scaling and curettage. Ferris40 showed a reduction in tooth mobility ranging from 13.6 percent to 77.3 percent two months after initial therapy; the average reduction for the entire test group was 24.6 percent. Although periodontal surgical healing is not influenced by tooth mobility, surgical treatment can decrease tooth mobility by 40 percent to 50 percent.[39-40] These studies indicate that initial therapy can decrease tooth mobility by approximately 20 percent to 25 percent, whereas surgical treatment can decrease mobility by an additional 40 percent to 50 percent.

Occlusal Adjustment

Since mobility is a risk factor for future attachment loss, it is questioned whether occlusal equilibration should

be performed to minimize these risks and whether it is effective. There are differences in opinion over this issue.

Occlusal adjustment has long been proposed as a method for the management of occlusal trauma. Muhleman[27] reported that mobility values are 30 percent higher in hypofunctional teeth than in hyperfunctional. With the re-establishment of bilateral balanced function by occlusal adjustment, mobility was reduced on the hypofunctional side by 18.1 percent and on the hyperfunctional side by 8.7 percent. Vollmer and Rateitschak[41] confirmed that occlusal adjustment could result in mobility reductions of 18 percent to 28 percent after seven to 30 days. While it is generally agreed that occlusal adjustment can reduce tooth mobility, views differ as to when in the therapeutic sequence occlusal adjustment is indicated.

Reflecting the European philosophy of prosthetic rehabilitation of patients with advanced periodontal disease, Nyman and Lindhe42-45 demonstrated that splinting or occlusal equilibration is indicated only if tooth mobility is extensive and may interfere with masticatory function or patient's comfort. Additionally they demonstrated that once mobility and periodontal disease have been controlled, teeth with secondary occlusal trauma and a history of increased mobility can be used as abutments for fixed prostheses or splints. Teeth with severe attachment loss may still be used if inflammation is controlled. It was advocated that these teeth be splinted cross-arch in prosthetic design for a favorable distribution of occlusal force. Conversely, teeth with persistently increasing mobility are not acceptable abutments and should not be used.

Based on various studies performed at the Eastman Dental Clinics, Zander and Polson[46] concluded that the single most important factor for successful periodontal disease management is plaque control, and most cases do not require occlusal adjustment or splinting. This is consistent with this group's experimental animal studies, which suggested occlusal trauma is not a co-destructive factor for further attachment loss. Occlusal adjustment was advocated only to improve a patient's comfort and function.

Caffessee,[47] Ramfjord and Ash[48] stated that occlusal therapy should be performed as part of the initial preparation phase of periodontal treatment whenever there is a functional indication for it. After the inflammation has been controlled, appropriate occlusal management may include occlusal adjustment, temporary or long-term splinting, stabilization appliances, orthodontic treatment, and restorative dentistry. The latter two definitive treatments were recommended to be performed at least one to two months or more after completion of periodontal surgery. Splinting was advocated only when mobility interferes with the health and comfort of the patient or when the mobility is progressively increasing.

This philosophy is supported by the findings by Burgett and colleagues[49] who studied 50 treated patients in the Michigan longitudinal periodontal study who were placed into the periodontal maintenance phase. Of this total population, 22 patients received occlusal adjustment and 28 patients were placed in the control nonadjustment group. After two years, it was concluded that those in the occlusal adjustment group who received conventional periodontal therapy, whether surgical or nonsurgical, had a more favorable clinical attachment level and gain of attachment than those in the nonadjustment group. In addressing the issue of whether initial tooth mobility is a risk factor for future attachment loss, these investigators noted that with occlusal adjustment, initial tooth mobility did not affect attachment response during this limited two-year period of study.

Dental Splint Therapy

A dental splint is an appliance designed to stabilize mobile teeth and allow for "normal" function within the limits of the reduced periodontium. The premise is that splinting will aid in the reduction of tooth mobility and create a more stable and favorable situation for periodontal repair. Splints are classified according to the length of service time and the therapeutic objectives. Temporary splints are utilized in the short term to help stabilize teeth during periodontal treatment. Provisional splints are used for limited duration, from months to several years, for diagnostic purposes. Permanent splints are for long-term use and may be of fixed or removable design.

Splinting has been advocated for stabilizing moderate to advanced tooth mobility. The goal of splint therapy is to reduce occlusal trauma and provide comfort during masticatory function. It may be a treatment of last resort, short of extracting the tooth. Restoratively, permanent splinting is used to stabilize teeth after orthodontic treatment and to prevent extrusion of unopposed teeth. Dental emergency providers and oral surgeons use splints to stabilize subluxated or avulsed teeth following acute trauma or transplantation procedures. Periodontally, splinting is used to stabilize the teeth and to facilitate therapy such as initial preparation, occlusal adjustment, and surgery.

The benefits of splinting teeth are based on clinical impressions rather than on scientific studies. Splinting has not been shown to reduce individual tooth mobility or enhance tissue

healing. Several studies[50-52] indicate that although splinting teeth may temporarily improve their mobility status, it does not reduce their mobility once the splint has been removed. The splint, in effect, masks the mobility status. This results in making the accurate assessment of individual tooth mobility a difficult task. Renggli and Schwizer[51] evaluated teeth splinted with copings and telescopic-designed prostheses. After 12 months, no improvement was observed after the splint was removed. These findings have been supported by Rateitschak and coworkers.[50,52] Kegel and colleagues[53] used a split-mouth design to evaluate the effect the effect of splinting on tooth mobility during initial periodontal therapy. After 15 weeks, the reductions in tooth mobility observed in the splinted and unsplinted teeth were similar, and any reduction in mobility could only be attributed to improved occlusal relationships and reduction in inflammation. Galler and colleagues54 designed a similar split-mouth study to evaluate the effect of splint on tooth mobility following periodontal surgical procedures. After healing, postsurgical mobility was similar for both splinted and unsplinted teeth. Despite the lack of objective improvement in therapeutic response, it is reasonable to splint teeth during periodontal therapy not only to reduce mobility, but also to provide for patient comfort and normal masticatory function during therapy.

Despite the lack of scientific support for splinting, many clinicians are of the opinion that it is valuable in achieving therapeutic success. Clinical reports by Amsterdam,[55] Cohen and Chacker,[56] and Nyman and colleagues[44] described periodontally handicapped patients with multiple missing teeth and advanced mobility who were treated successfully over the long term (**Figure 5**). In these reports, features contributing to the success of the reported cases included control of periodontal inflammation, good oral hygiene in the presence of healthy periodontal tissue, adequate number and distribution of abutment teeth, cross-arch stabilization, and control of the occlusion. Though the success of these cases is dramatic and impressive, it is important to recognize that these are case reports of highly motivated patients with a high degree of commitment toward oral hygiene and periodontal maintenance. Detail assessment of clinical findings as well as patient compliance is critical for success in defining the prognosis in this type of advanced prosthetic treatment.

The health of the periodontium greatly influences the ability of each tooth to withstand occlusal force. Prognostically, it is important that there is a distribution of occlusal stops with healthy periodontium. A case in point is the dentition where only maxillary and mandibular anteriors are present and the patient refuses to wear a partial denture. The occlusal forces can be such that all of these teeth may be mobile despite adequate periodontal support. The good news is that with the elimination of periodontal inflammation and the addition of posterior support, there is often decreased mobility. Additionally, with the wider acceptance of dental implants, dental prostheses may provide occlusal support that previously was not biomechanically possible based on conventional prosthetic design (**Figure 6**). Advances in dental implants and restorative materials have created greater opportunities to better manage the distribution of occlusal forces. These advances can improve case prognoses in ways previously thought to be clinically impossible.

Conclusion

The thesis of this paper is to discuss how individual tooth and overall treatment prognosis is affected by the occlusal harmony of the masticatory apparatus. In a healthy situation, the masticatory apparatus – composed of the teeth and its supporting structures, temporomandibular joints, and associated neuromusculoskeletal structures – operates in an integrated and dynamic manner. Loss of integrated function, such as the structural integrity of the tooth through endodontic treatment or periodontal disease, can result in adaptive changes in response to occlusal force. Should the adaptive responses not be able to compensate for the occlusal forces, the prognosis may worsen significantly.

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Occlusal Considerations for Implant Restorations in the Partially Edentulous Patient

By Donald A. Curtis, DMD, Arun Sharma, BDS, MS; Fredrick C. Finzen, DDS; and Richard T. Kao, DDS, PhD

ABSTRACT The type and frequency of complications associated with dental implants has changed during the past decade. As more-successful rates of osseointegration have resulted from improved surgical protocols and materials, the major complications have become restorative-related rather than surgery-related. Recent studies indicate that restorative complications with implant-retained restorations occur at rates of 10 percent to 77 percent over a three-year period. Many of the restorative complications can be minimized with careful treatment planning and coordination of care. However, because implants lack the stress release associated with a periodontal ligament, impact loading to restorative materials and the crestal bone remains potentially more damaging with implant-supported restorations. This article discusses the biomechanical implications of implant restorations and outlines occlusal considerations designed to decrease restorative complications.

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Implant-retained prostheses have become a well-established option to treat the partially edentulous patient and often represent an improvement over traditional removable partial dentures. Improved support, a more stable occlusion, preservation of bone, and improved patient acceptance are reasons an implant-supported prosthesis should be considered.[1] Additionally, long-term oral health is often improved by using an implant because less-invasive restorative procedures are required for the remaining dentition.[2,3] Despite highly predictable techniques for achieving osseointegration and the recognized physiologic and functional benefits of an implant-supported prosthesis, restorative complications often occur.[4-7]

Those complications occur with a reported frequency of 10 percent to 77 percent over a three-year period.[4-9] Complications are more common in screw-retained implant crowns rather than cemented restorations,[8] and they occur more frequently with single-tooth implant crowns than with multiple-splinted units.[6] Reasons for the high complication rate include anatomic limitations such as bone volume or quality, spacing issues such as excessive or inadequate horizontal or vertical

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restorative space, and the unique biomechanical loading that occurs with endosseous implants. Because implants lack the stress release associated with a periodontal ligament, impact loading to restorative materials and the crestal bone is potentially more damaging.[10-11] As a result of anatomic limitations and biomechanical differences, ideal implant placement and biomechanical loading is not always possible. Follow-up problems can include reversible complications such as screw loosening, screw fracture, or porcelain or acrylic resin fracture. Irreversible complications can include loss of bone, loss of osseointegration, or implant fracture.

This article will outline occlusal considerations in the partially edentulous patient when using dental implants. The emphasis will be on posterior occlusion because molars are the most commonly replaced teeth and posterior quadrants are the most common areas of restorative complications with implants. Masticatory forces, types of restorative complications seen with overloading implants, and the ways in which occlusal considerations can decrease restorative complications will be reviewed.

Masticatory Forces on Teeth and Implants

Understanding normal masticatory forces is important when treatment planning with dental implants. Masticatory forces developed by a patient with a quadrant restored with an implant-supported fixed prosthesis are equivalent to those of a patient with natural dentition.[12] However, forces passed to crestal bone and impact forces are greater with implant restorations than with natural teeth.[10,11] Occlusal modifications and restorative changes can decrease the stress on crestal bone and restorative materials.

Normal masticatory forces are mostly vertical and vary with age, gender, muscle mass, skeletal form, and measured position in the arch.[13] Occlusal contact time totals about 17 minutes a day, eight of which occur during mastication.[14] Most normal masticatory forces are vertical along the long axis of the dentition and average less than 70 Newtons with a typical Western diet.[15] In general, the greatest forces would be expected in the first molar area of a young stressed male with a square-angle jaw chewing on a hard substrate. Conversely, lesser forces would be expected in a sedate elderly female with a long midface measured in the incisor area when chewing on a soft substrate.

Non-axial masticatory forces are generally much less than vertical forces and are generated from elliptical jaw motion and contact on inclines of cusp teeth. Non-axial masticatory forces vary with the chewing stroke and location in the mouth but are generally less than 50 Newtons in the buccolingual direction and 20 Newtons in the anterior-posterior direction.[15] Patients lacking anterior disclusion, lacking proximal contacts for support, having a cross-bite, or having limited posterior natural tooth contacts would be at higher risk for generating great horizontal and anterior-posterior forces.

High-Risk Patients

Patients at high risk for excessive forces would be those with bruxing habits, defined as a nocturnal grinding that can include both a vertical and horizontal component.[14] More than 20 percent of the population are clinically active bruxers at some point in their lives.[16,17] Identification of bruxers is important before treatment planning with implants. Studies have shown that bruxism often results in horizontal forces several times during a night for periods up to an hour. Electromyographic studies have shown that bruxing forces are generally at the level of the patient's maximal biting force, approximately seven to eight times that of normal masticatory forces.[18] In a study of 4,045 implants followed during a five-year period, all patients with fractured implants (eight patients, or 0.2 percent) had parafunctional habits; and bone loss preceded the implant fractures.[19] In a three-year study of 1,279 fixtures, Quiryen determined that 27 percent of the fixtures in a high-risk group of individuals with parafunctional habits either failed or had more than 1 mm of bone loss during the second or third year of loading.[20] For the low-risk group, without parafunctional habits, the percent with failure or bone loss greater than 1 mm was 2.7 percent.[20] Bruxing is not an absolute contraindication to implant restorations, but caution and careful treatment planning would be essential in such cases.

Complications From Overloading Implants

Complications from overloading implants are often a result of unanticipated forces on restorations not designed to tolerate either the static or cyclic loading of the patient's normal masticatory forces and/or parafunctional habits. Complications from overloading implants are more common in posterior restorations and increase dramatically when a prosthesis is nonpassive.[6] Complications are more common in the maxilla than mandible and occur more frequently in screw-retained than in cemented restorations.[8] The most serious biologic response to overloading is crestal bone loss. The most common restorative complications of overloading are screw loosening, screw fracture, and porcelain fracture.

Crestal Bone Loss

Crestal bone loss around endosseous implants is not fully understood but likely occurs for several reasons, some of which are related to occlusal loading.[21,22] Crestal bone is susceptible to bone loss because of the difference between implant and bone elasticity. Because titanium is so much stiffer than bone, a stress gradient occurs at the interface of the bone and implant, placing the crestal bone at risk for resorption. Additionally, the crestal bone is often immature at the time of initial prosthetic loading and susceptible to osteoclastic activity. In addition, the flex of the tooth or dampening effect from the periodontal ligament is not equivalent with a rigid implant or metal restoration, so more force is passed to the crestal bone. Human trials, animal studies, and finite element analysis studies support the theory that repetitive overloading beyond a physiologic threshold can cause microfractures and osteoclastic activity to crestal bone, resulting in bone loss.[6,19,23-27]

Overloading of an implant can occur more easily, with fewer symptoms, and with more permanent damage than overloading of teeth. This is because implants do not have a surrounding supportive ligament that can provide increased proprioception, better distribution of forces, sharper pain perception, or adaptations to overloading, such as thickening of the periodontal ligament[28-29] (**Table 1**).

Screw Loosening

Screw loosening has been reported to occur with a three-year frequency of from 3 percent to 38 percent in screw-retained posterior restorations.[4,5,8,30,31] Screw loosening is more likely in single-unit restorations, occurs more often in the molar than premolar area, and can often be related to excessive loading. Screw loosening occurs when compressive occlusal forces are higher than the tension in the screw-implant assembly that holds the components together (the clamping force).[32] Forces tending to separate the screw-implant assembly can be related to prosthesis design or misfit, excessive or off-axis forces that can occur from a premature occlusal contact or contact on a cantilever, an offset, or a steep cusp angle. The clamping force will also be decreased when an implant restoration is nonpassive.[32]

When an abutment screw to an implant restoration loosens, it is important to check the fit of the implant/restoration interface with a radiograph. It is also important to verify that a proximal contact is not so tight that the restoration is not completely seated because of lateral pressure. The internal of the hex and screw threads should be inspected for damage.

Occlusal considerations and restorative modifications can decrease the incidence of screw loosening (**Table 2**). When checking the occlusion, make sure a prematurity does not exist. If steep cusp angles are found, they should be flattened, which will decrease the potential for exceeding the clamping force of the screw-implant assembly.[32,33] If the occlusal table is wide, narrowing it will decrease both the offset and the potential for exceeding the clamping force of the screw-implant assembly. Screw loosening occurs less frequently when a wide-diameter implant and a machined gold cylinder rather than a narrow diameter implant or castable wax sleeve is utilized. Replacing the titanium screw with a gold-alloy screw is reported to increase the clamping force or pre-load and has been found to be helpful but has not been documented by clinical studies. Additionally, a torque driver can be helpful to standardize the torque level.

Repeated complications such as screw loosening, screw fracture, or porcelain fracture are often warning signs that more-serious complications – such as implant fracture or bone loss – may occur. In a retrospective study, Rangert showed that reversible complications such as screw loosening occurred in more than 60 percent of the restorations before irreversible complications such as implant fracture occurred.[6] When screw loosening or screw fracture have occurred, the use of a nightguard should be considered.

Screw Fracture

Screw fracturing usually occurs for different reasons than does screw loosening. While screw loosening most often occurs when occlusal compressive forces are beyond the threshold of clamping forces, screw fracturing usually occurs from excessive shear forces[34] (**Figures 1A, B, and C**). Screw fracturing often indicates that excessive lateral forces are occurring and should be considered a major warning sign of more-serious complications. Studies have shown a higher incidence of bone loss associated with restorations where screw fractures have occurred.[6] A verification of fit and an optimization of occlusal factors should be completed as would be done for a patient with screw loosening. Careful consideration should also be given to major changes in the prosthesis. The sectioning of a cantilever, the addition of an implant and fabrication of a new prosthesis, or a prosthesis with a new design should be considered.

Materials Fracture

Materials fracture on implant-retained restorations is one of the more common complications that leads to refabrication of a prosthesis.[35] Material fractures can occur soon after loading but can also occur years after delivery because of material fatigue and deformation (**Figures 2A and B**). The

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Table 1

The Advantages of a Periodontal Ligament

Natural dentition with a PDL allows:	Restorative modification with implants:
Better tactile and sensory proprioception, 10X better acuity at low levels of biting force[26]	Patient feedback less reliable for occlusal adjustment, with perception of force stimulation duller and more difficult to locate.[27]
Better stress distribution to alveolar bone with suspensory ligament	Ankylosed and rigid implant results in 80% of occlusal forces passed to crestal bone, so consider a rigid framework for better stress distribution and progressive loading.
Signs and symptoms of overload, including thickened ligament, tooth mobility, wear facets, fremitis and pain	Few warning signs or symptoms of overload. see screw loosening, screw fracture, abutment fracture, or bone loss.
Easier delivery of restoration because of PDL movement	Ankylosed implant makes it more time- consuming for adjustment of contacts, and non allowance for supereruption

incidence of materials fracture is higher with implant-retained restorations than the equivalent restoration on natural dentition for three major reasons. First, because implants lack the stress release possible with a periodontal ligament, impact forces are higher on implant-retained restorations; and fatigue, creep, and permanent deformation are more likely to occur. Second, with the small base for implants (3 to 6 mm) compared to the wider base of natural teeth (10 to 12 mm), even a well-designed metal frame for a porcelain-fused-to-metal restoration can have areas of unsupported porcelain that can fracture. Third, higher stresses within the implant-retained restoration can occur close to the screw-retained access hole resulting in fractures.

When selecting materials for an implant-retained prosthesis, options include various acrylic resins, gold, or porcelain. Transient shock absorption is best with a softer material like an acrylic resin, but static loading is not influenced significantly by the veneering material.[36,39] In individuals at low risk for bruxism or excessive force transmission, gold, porcelain, or acrylic resin are all viable options. Although some authors have determined that there is a reduced rate of fractures to abutments and screws when using acrylic resin,[38] the rate of acrylic resin fracture and the need for repair is significantly higher than when porcelain is used.[35] An important consideration is wear compatibility between the opposing arches.

Strategies to Minimize Overloading of Implants and Implant Components

Treatment Planning

Complications with dental implants are most often the result of inadequate treatment planning and lack of coordination of care. Considerations of bone density and volume, anticipated loads, and planned restorative design are all important to review before the number, length, and diameter of implants are determined. Treatment planning for an implant-supported restoration also includes identification of patients at high risk for developing excessive force to the implants, restorative designs and occlusal considerations to minimize and broadly distribute stresses, and an awareness that careful follow-up is required.

A complete history and detailed examination is important to identify patients at high risk for occlusal overload and/or restorative complications. Important considerations include how patients have lost teeth and whether they have a history of bruxism, clenching, or parafunctional habits. If a patient has lost teeth due to fracturing, he or she is at higher risk for overloading implants than if teeth were lost due to periodontal disease.[39] Additionally, if a patient's maxillomandibular relationship includes excessive anterior-posterior or lateral discrepancies, e.g., a skeletal class II patient, he or she would be at increased risk for non-axial loading. Clinical signs or symptoms that warrant careful consideration include a square-angle jaw, large masseter muscles, lack of anterior disclusion, wear facets, fremitis, periodontal ligament thickening, or few posterior tooth-to-tooth stops.

Restorative and Occlusal Considerations

The fabrication of an implant-supported restoration in a posterior quadrant requires several modifications to the equivalent procedures on natural dentition. Reduction of stress to implants and restorative components is recommended and may be necessary even though the equivalent step is not as critical with natural dentition. A definitive restoration that includes a narrow occlusal table and shallow cusp anatomy is likely to decrease the forces on prosthetic components and crestal bone[34] (**Figures 3a and b**). Indexing and soldering have also been shown to decrease stress to crestal bone.[40] Splinting of single units in patients at risk for high occlusal loading should be considered as should judicial use of cantilevering. These recommendations apply to use of the traditional 3.75 mm diameter implant with an external hex and would be modified if wider platform or internal hex

Table 2

How Restorative Considerations and Prosthetic Procedures Differ Between Teeth and Implants for a Posterior Fixed Restoration in the Partially Edentulous Patient

Variable	*Natural dentition*	*Implants*
Shallow cusps	Not as important because PDL able to absorb forces	Decreases lateral stress to implant restoration and crestal bone
Narrow occlusal table when restoring posterior quadrant	Not as important because tooth starts from wider base, has PDL to absorb forces, and has easier and more predictable metal design	Improves access for cleaning, decreases stress to bone, and decreases potential fracture from unsupported porcelain
Splinting	Not usually necessary	Often important in posterior quadrants for force distribution
Indexing and soldering	Often not required because marginal fit can be evaluated and the PDL provides movement	Necessary because more difficult to evaluate fit. Also, better fit results in decreased stresses to crestal bone
Cantilevers	Only after careful consideration	Increases complications because of increased potential for non-axial loading and concentrates stress at crestal bone level
Occlusal offset (buccal-lingual)	Usually not a problem	Often a problem in maxillary posterior due to normal resorption patterns
Restorative material	Usually do not have to consider dampening effect because of PDL	Better dampening effect with acrylic resin but higher wear and fracture rate

components were used.

A posterior implant-supported prosthesis with flat cusp angles stresses the bone, implant components, and restorative materials less than the equivalent prosthesis with steeper cusp anatomy. The more complex the occlusal surface, the greater the potential for wedging of food and increased lateral force transmission.[41] Therefore, wide occlusal groves and fossae are recommended to decrease the potential for the wedging of food (**Figures 4a and b**). Additionally, anterior disclusion is easier to develop when posterior occlusal anatomy is shallow and the posterior occlusal plane is flat.

A narrower occlusal table should be considered in the diagnostic wax-up, provisional, and definitive restoration. Normally, a flatter and narrower occlusal table would invite tooth migration, but with an ankylosed implant restoration, that is not a problem. A narrower occlusal table also facilitates easier access for home care.

The splinting of posterior implants is important to consider for patients requiring distribution of forces. Although the total force passed to crestal bone will remain the same for a given load, stress distribution can be manipulated by splinting.[41] Implant fractures as well as screw loosening occur less frequently when implants are splinted together.[6] When splinting posterior units, indexing and soldering improves the fit and decreases the stress to the prosthetic components and crestal bone. It is often difficult to clinically evaluate the subgingival marginal adaptation of implant castings, so indexing and soldering is highly recommended. If the abutment screw on a multiple-splinted implants binds as it is tightened, it is often a sign that indexing and soldering is needed to provide passivity of the restoration.

Cantilevers significantly increase stresses to the crestal bone, and caution should be especially high when they are used opposite natural dentition. Lindquist and Ahlqvist found more bone loss around fixtures with long cantilevers.[21,22] Although traditional bone-anchor bridges used 10 to 20 mm cantilevers opposing an edentulous arch, modern research has shown stresses to be significant when opposed by the increased forces possible in natural dentition.

The cantilever length possible is influenced by biomechanical factors. The location of the cantilever, anticipated occlusal load, diameter, number, and surface characteristics of the implant, anterior-posterior spread, bone quality, and rigidity of the superstructure should be considered before cantilevers are planned (**Figures 5a and b**). If there is not sufficient rigidity, the anchorage unit closest to the load will be excessively loaded. Likewise, if the fit between the implant and prosthesis is not accurate, some of the implants will be excessively loaded while other units will not be loaded.

The delivery of an implant-retained posterior restoration involves first checking the proximal and occlusal contacts. It is imperative that contacts be adjusted until light proximal contacts occur so that the restoration is fully seated and the seating is verified with a radiograph. Occlusal contacts are checked next and the opposing dentition adjusted if it is believed that the centric contact can be brought closer to the long axis of the implant. The centric contacts are adjusted with light occlusal contact for two reasons. First, the opposing natural dentition is often compressed; and, secondly, progressive loading is possible

Figure 1a. A radiograph of a 3.75 mm diameter implant replacing a molar in a patient with a bruxing habit.

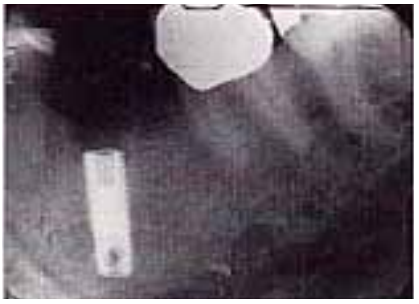

Figure 1b. A radiograph showing the fractured implant after several appointments to tighten loose or broken screws.

Figure 1c. The fractured implant. Screw loosening and, in particular, screw breaking are warning signs that more serious problems may occur.

Figure 2a. Clinical example of fractured porcelain due to poor metal design that did not provide porcelain support.

Figure 2b. Laboratory example.

Figure 3a. Clinical example of a posterior restoration with a slight offset, shallow occlusal morphology, and a narrow occlusal table. The major benefits of a restoration with a narrow and shallow occlusal anatomy are improved access for oral hygiene and decreased potential for lateral loading.

Figure 3b. Another view.

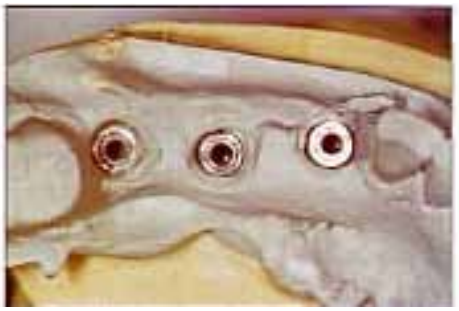

Figure 4a. Laboratory example of a posterior restoration where shallow occlusal anatomy allowed anterior disclusion by natural dentition.

Figure 4b. Clinical example.

Figure 5a. Example of a patient with a cantilever.

Figure 5b. Another view. Anterior cantilevers are generally less problematic than a distal cantilever.

when starting with light occlusion on an implant. Any occlusal prematurity will result in increased vertical and horizontal loading.

Lateral contacts are then evaluated. Whenever possible, anterior natural teeth should disclude the posterior implant crowns. When anterior disclusion is not possible, and lateral forces will knowingly be placed on the posterior implant crowns, it is advisable to treatment plan additional wide-diameter implants. A wider diameter implant is almost always an advantage due to increased surface area contact (approximately 25 percent for each 1 mm increase in diameter) and a broader occlusal platform. If lateral forces cannot be eliminated, they should be designed to equally distribute over as many teeth and implants as possible. If excessive forces are anticipated, either an alternative to an implant-supported prosthesis or a removable overpartial can be considered.

Posterior implant restorations that follow an arc are less prone to implant fracture and certain other restorative complications than a posterior quadrant that is restored in a linear configuration.[6] It has also been shown that restorative complications decrease when three rather than two implants are used to restore a posterior quadrant.[6] It therefore makes sense that when a posterior quadrant is restored, three implants in a nonlinear configuration be considered. Use of wide-diameter implants will often provide an equivalent benefit to the nonlinear configuration.

Restorations can be cemented, screw-retained, retained with a lingual set screw, or retained with substructure and attachment. Each method for retaining an implant restoration has indications, and occlusal relationships can influence the prosthetic choice. For example, the occlusion is often easier to control and axial loading more favorable with a cemented rather than screw-retained restoration because it is often easier to create a narrow occlusal table without the restriction in dimensions of a screw access hole. In the maxillary anterior, lateral movements are often smoother if not interrupted by a screw access hole. Wear compatibility to the opposing arch is often easier to establish with a cemented restoration because occlusal contacts are often directly over the screw access hole that is covered by composite and opposed by porcelain or metal.

In patients where a cantilever, wide off-set, or future modification in prosthetic design or prosthetic needs are planned or anticipated, a retrievable restorative option such as a screw-retained prosthesis should be strongly considered. Additionally, a screw-retained prosthesis is often necessary when minimal interocclusal space is present. Although reported complications are more common in screw-retained prostheses as opposed to cemented restorations, many of the reported complications represent the clinician's early learning curve and product development. With improved machining of implant components, the improved pre-load possible with gold-plated screws, and an increased awareness of component limitations, screw-retained restorations have become very predictable and preferable to cemented restorations in many clinical situations.

When complications such as abutment screw loosening occurs with a cemented crown, a new restoration may be required. Additionally, soft tissue complications resulting from excess cement have been reported[42] and are especially problematic when an implant-supported crown is cemented on an abutment with a subgingival margin where inflamed and/or unattached tissue is proximal to the implant. A screw-retained prosthesis is recommended when retrievability is a priority, and the use of an all-gold restoration is recommended when esthetics do not indicate a ceramo-metal restoration.

Monitoring and Follow-up

More follow-up is needed with implants than with traditional fixed prosthetic work. When a screw loosens, it is important to document the event so that appropriate steps can be taken if repeated screw loosening occurs. Likewise, it is important to monitor the bone level with bitewing radiographs twice in the first year because other signs and symptoms of potential overload are unlikely to be evident. The occlusion should also be evaluated yearly to make sure prematurities do not exist and that the anterior dentition has not worn, which could place more lateral stress on posterior implant restorations.

A nightguard should be fabricated for patients at high risk for occlusal overload. These would include patients with a history of bruxism or clenching, patients with lateral offsets or cantilever, or implant restorations that do not have a proximal natural tooth.

Conclusion

Implant restorations are a "high stakes" treatment requiring a substantial financial and time commitment. Unanticipated restorative complications can be disheartening for both patient and clinician. It is important to educate the patient about potential complications before starting an implant restoration. Many of the complications are related to force transmission and can be controlled with careful treatment planning, which often leads to a better distribution of forces. It is important to identify patients likely to overload the planned restoration and to be aware of warning signs that overloading may be occurring.

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Occlusion: An Orthodontic Perspective

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ABSTRACT In recent years, orthodontists have examined their concepts of occlusion. In current literature, at professional meetings, and in continuing education courses, one hears an ongoing discussion of condylar position and mandibular border movements in relation to occlusion. There is a wide variation in opinion as to whether dental occlusion and TMJ function are interdependent. The authors have adopted a dynamic concept of dental function to replace the traditional static view of molar relationship and incisor overlap. This article discusses how occlusion has evolved in orthodontics and reviews Andrews' six keys to ideal static occlusion, the goals of ideal dynamic occlusion, and the six signs of developing malocclusions. The authors also review the literature on the relationship between orthodontics, occlusion, and TMD.

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Edward H. Angle, the father of modern orthodontics, is credited with the definition of normal occlusion as well as classification of malocclusions.[1] According to Dr. Angle, normal occlusion exists when the mesiobuccal cusp of the upper first molar occludes with the buccal groove of the lower first molar. This definition of occlusion, based on a static position of the teeth in closure, launched orthodontics as the specialty dedicated to treating deviations from Angle's definition of normal occlusion.[2]

B.B. McCullum, the father of modern occlusion, and the founder of the Gnathological Society, introduced a more dynamic concept of occlusion.[3] His concept of occlusion, along with that of Stallard, Stuart, Huffman, and Regenos, focused on cusp contact during functional movements.[4-6] The dynamic concept was readily adopted by prosthodontists and restorative dentists whose challenge was to restore teeth to ideal anatomic form. The dynamic concept of occlusion provided practical guidelines for building cusp heights and placing grooves to facilitate functional jaw movements without functional interferences.

There is more acceptance than ever for a dynamic concept of occlusion; however, the concept remains controversial. There is no scientific evidence to show whether such a concept is valid. In such circumstances, one must be guided by clinical judgment. It seems prudent when planning and executing orthodontic treatment to include a consideration of mandibular movements. Producing fine

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orthodontic results is a major technical challenge, and producing an occlusion that coordinates with temporomandibular joint function increases the complexity. The introduction of pre-adjusted orthodontic brackets, new wires with remarkable range of motion and resiliency, and the diagnostic techniques to relate occlusion to skeletal landmarks and mandibular movements have increased the sophistication of treatment goals and the ability to achieve them.

Cusp-Fossa vs. Cusp-Embrasure Occlusion

Charles Stuart[5] stated that there was a mesial and distal limit to a well-functioning occlusion. The mesial limit was referred to as a "tooth-to-tooth" and the distal limit was referred to as the "tooth-to-two-teeth" occlusion. Huffman and Regenos[6] later summarized the two types of occlusion described by Stuart, referring to them as "cusp-fossa" and "cusp-embrasure" occlusion.

In a cusp-fossa occlusion, as also advocated by Thomas,[7] each mandibular buccal cusp occludes into the fossa of the maxillary counterpart and each maxillary lingual cusp occludes into the fossa of the mandibular counterpart (**Figure 1**). This occlusal scheme, which places maxillary teeth slightly mesial of Angle Class I relationship, very effectively directs forces along the long axis of teeth, an arrangement that encourages positional stability. Furthermore, food impaction between teeth is minimized since no cusp tips strike opposing embrasures, and there is less tendency for wear of cusp tips and occlusal attrition.

In a cusp-embrasure occlusal scheme, all teeth, with the exception of mandibular central incisors and maxillary third molars, have a tooth-to-two teeth relationship (**Figure 2**). Each maxillary tooth is distal and facial to the mandibular counterpart (**Figure 3**). Mandibular buccal cusps contact maxillary embrasures. Maxillary lingual cusps are in a fossa relationship with the mandibular counterpart (except for the distolingual cusps of the maxillary first and second molars).

It is useful that there is a mesiodistal range for a nicely functioning occlusion. Anatomic considerations of teeth (e.g., tooth size discrepancies, atypical teeth, and over-retained primary teeth in place of congenitally missing teeth), skeletal disharmonies, and atypical extraction patterns may favor one occlusal scheme (**Figure 4**). The terms distal-normal, mesial-normal, and median-normal (an occlusal relationship midway between the other two) have been used to describe a satisfactory finished orthodontic occlusion.[8]

Current orthodontic goals of incisor overlap and overjet and of interincisal angle lead the orthodontist to prefer cusp-embrasure as the goal. This scheme provides for freedom of movement in lateral and protrusive excursions with protective cuspid and incisor function.

Six Keys to Ideal Static Occlusion

As discussed above, from a static occlusal standpoint, Stuart's distal limit (tooth-to-two teeth), also referred to as the Angle Class I occlusion, is the typical goal in orthodontic treatment. In a 1972 landmark article, Andrews9 described six significant characteristics in his study of 120 cases of non-orthodontic normal occlusions that have since become additional goals for a well-finished orthodontic case. It is important to note that the subjects in Andrews' study all had naturally straight teeth with pleasing smiles; their casts occluded in a generally ideal position, and they had never received any orthodontic treatment. The six characteristics, which are referred to as the six keys to normal occlusion, are as follows:

- The first key: molar relationship. The distobuccal cusp of the upper first molar contacts the mesiobuccal cusp of the lower second molar. The mesiobuccal cusp of the upper first molar falls in the groove between the mesiobuccal and middle-buccal cusps of the lower first molar. The proper relationship allows the cuspids and bicuspids to enjoy a cusp-embrasure relationship buccally and a cusp-fossa relationship lingually (**Figure 5A**).
- The second key: crown angulation (tip). The gingival portion of the crowns of all the teeth is more distal than the incisal or occlusal portion of the crowns. The long axis of all teeth, except molars, is the mid-developmental ridge of the facial surfaces of the teeth. The long axis of the molar is considered to be the buccal groove and its extension to the gingival (**Figure 5B**).
- The third key: crown inclination (torque). This refers to labiolingual inclination of the anterior teeth or buccolingual inclination of the posterior teeth. The upper incisors have a labial crown inclination (positive torque). The lower incisors have a slight lingual inclination (negative torque). The upper cuspids and posterior teeth have lingual crown inclination (negative torque). The inclination is similar for upper cuspids and bicuspids and slightly more pronounced in the molars. Lingual crown inclination (negative torque) also exists in the lower cuspids and posterior teeth and progressively increases from the cuspids through the second molars (**Figure 5C**).
- The fourth key: no rotations. Rotated teeth occupy more space within the

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dental arch (**Figure 5d**).
- The fifth key: no spaces. All contact points are tight (**Figure 5e**).
- The sixth key: the occlusal plane. The occlusal plane may vary from generally flat to a slight curve of Spee (**Figure 5f**).

These important findings gave rise to pre-adjusted orthodontic brackets, incorporating specific built-in adjustments that produce ideal tip, torque, in/out, and rotational tooth positions, significantly reducing the need for archwire adjustments throughout the course of orthodontic treatment.

Goals of Ideal Dynamic Occlusion

Dynamic occlusion requires that the teeth function during jaw movements free from premature contacts and interferences. To achieve this, one must pay particular attention to static tooth positions, to condylar position upon closure into occlusion, and to mandibular border movements as determined by the temporomandibular joints. Roth10 has demonstrated that if the orthodontist is able to finish cases to Andrew's six keys and establish maximum intercuspation in harmony with centric relation, then Stuart's goals of ideal functional occlusion can be achieved. Although still not universally accepted and practiced by all orthodontists, many of these functional occlusion principles have received significant recognition in the specialty.

Essential to the stability of an ideal occlusion is the relationship between centric relation (CR) and maximum intercuspation (MI). Centric relation will permit seating of the condyles into the glenoid fossa against the articular discs at the most superior position against the eminentia and also centered in the transverse plane of space (**Figure 6**). In an ideal orthodontic finish, this condylar position should occur when upper and lower teeth are closed into MI. It has been shown that the displacement of the condyles from the above position caused by intercusping of teeth (i.e., CR-MI discrepancy) should ideally be less than 1 mm vertically and horizontally and less than 0.5 mm transversely.[11,12]

- To achieve optimal functional occlusion, the teeth should be positioned so that they create what has been termed a mutually protected occlusal scheme. In this scheme, posterior teeth protect anterior teeth from lateral stress at full closure; and the anterior teeth protect posterior teeth from lateral stress during mandibular movements, as long as the condyles are permitted a gliding movement along the eminentia. In MI, there are simultaneous occlusal contacts around centric cusps of posterior teeth directing the closure stress along their long axes. In addition, there is no actual contact of the anterior teeth in MI, but a slight clearance detectable by a 0.0005-inch thickness shimstock. Upon movement of the mandible in any direction from full closure (left and right lateral excursions and straight protrusion), the anterior teeth and canines provide a gentle guide ramp that allows the condyles to traverse the eminentia, and disclude the posterior teeth on the working and balancing sides (**Figures 7a through d**). The condylar guidance expressed by the morphology of the joints is the major determinant of the overbite-overjet relationship of anterior teeth and canines, and the major determinant of posterior tooth positioning and archform.11 Generally speaking, when teeth are in MI with the condyles seated in CR, there must be 4 mm of vertical overbite and 2 to 3 mm of overjet from the incisal edges of the maxillary incisors to the facial surfaces of the mandibular incisors and 1 mm of overjet from the tip of the maxillary canine to the facial surface of the mandibular canine.

Mounted Models in Diagnosis and Treatment Planning

For diagnosis and treatment planning, orthodontists have traditionally relied on hand-held study casts trimmed with an MI interocclusal wax registration (**Figure 8**). Many orthodontists analyze the functional status of the patient's occlusion as part of their diagnosis and treatment plan. To that end, study casts are mounted on a semi-adjustable articulator with a CR interocclusal wax registration. To produce such a wax registration, the operator must guide the mandible into centric relation by seating the condyles in a superior-anterior direction within the glenoid fossa (**Figure 6**). This is accomplished by supporting the angles of the mandible in a superior direction while pushing gently down on the chin and asking the patient to relax and close slowly (**Figure 9a**). Although different CR interocclusal wax registration techniques have been proposed, the two-piece "power centric" technique has shown merit in seating the condyles as close to CR as possible (**Figure 9b**).[12-14] The term power centric refers to the use of the patient's closure muscles (masseter, medial pterygoid, and the superior head of the lateral pterygoid) to seat the condyles in the desired direction.[11]

Using centric relation mounted study casts (**Figure 9c**), one can evaluate the following aspects of the dental-orthopedic complex:

- Relate the position of the maxilla to the cranial base;
- Relate the mandible to the maxilla with the condyles seated in centric relation;

Figure 1. Cusp-fossa (tooth-to-tooth) occlusion (From McNeill C, ed, Science and Practice of Occlusion. Quintessence Publishing, Chicago, 1997, p 408).

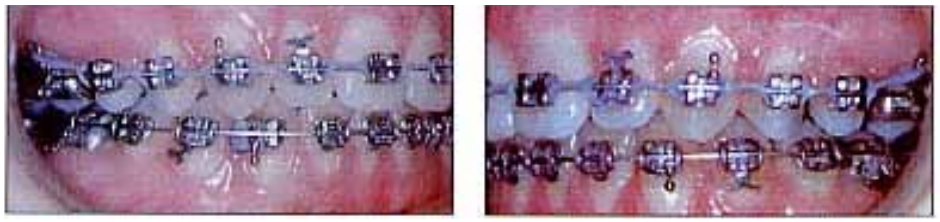

Figure 2. Cusp embrasure occlusion (tooth-to-two-teeth).

Figure 3. Cusp-fossa (above) vs. cusp-embrasure occlusion (From McNeill C, ed, Science and Practice of Occlusion. Quintessence Publishing, Chicago, 1997, page 315).

- Plan treatment to a reproducible condylar position, allowing examination of excursive mandibular movements; and
- Detect the point of initial tooth contact, unmasking occlusal interferences and evaluating the cant of the occlusal plane.[15]

The degree of discrepancy between CR and MI can not only be qualitatively assessed, but also quantitatively measured in three dimensions of space using additional instrumentation. The condylar position indicator and mandibular position indicator are instruments used with the Panodent and SAM articulators, respectively. They are designed to record the position of the condylar axis and measure CR/MI discrepancy in three planes of space and have been demonstrated to be both accurate and reliable (Figures 10A and B).[16-19] One can bring this information to the lateral cephalogram, which is typically taken in MI, and correct the mandibular position to CR on the tracing of the cephalogram prior to cephalometric analysis (**Figure 10C**). This, in addition to the CR mounted models, will allow the orthodontist to develop a diagnosis and treatment plan while accounting for centric relation.

Mounted study casts are only as accurate as the interocclusal and facebow record that was used to construct the mounting. The accuracy of the interocclusal record (wax bite registration) is only as good as the ability of the practitioner in registering the patient's bite. The possibility of correctly registering that bite is directly dependent on whether the patient's muscles of mastication are relaxed (i.e., without spasm or splinting), and the condyle is balanced or stable, without strain or stress within the articular fossa.[20] It is critical to identify the patient's proper CR before any orthodontic treatment is initiated, rather than see it surface halfway through the treatment. As the position of teeth is altered with orthodontic appliances, the patient's MI adapts continuously, and the only reliable reference point is centric relation. There are, however, times when capturing a reliable CR record on a patient is unlikely, due to muscular interventions. In such cases, a period of splint (orthotic) therapy, prior to active orthodontic treatment, can deprogram the patient's muscular and proprioceptive influences, allowing uninhibited condylar seating (**Figure 11**).

Developing Malocclusions: Six Warning Signs in a 7-Year-Old

Most referrals for orthodontic treatment are occlusion-related.[21] Many warning signs of developing malocclusions appear in the early mixed dentition. Ideally, children should be screened for orthodontic treatment no later than age 7, when the posterior occlusion has been established by the eruption of the six-year molars. This allows the orthodontist to evaluate anteroposterior and transverse relationships of the occlusion, as well as any functional mandibular shifts. The presence of permanent maxillary and mandibular central and lateral incisors reveals arch length discrepancies, habit patterns, and vertical dimension problems such as deep bite, open bite, or gummy smile. Most facial asymmetries appear by age 7. To raise the awareness of the public and establish an easy-to-follow set of guidelines for general practitioners, the California Association of Orthodontists has introduced a brochure called "Bite Down Early" that outlines the six warning signs in 7-year-olds (this brochure may

be ordered by calling the California Association of Orthodontists at [415] 441-2416). [22]

Six Warning Signs

- Is there excessive horizontal overlap (overjet)? Protrusion of the upper front teeth (**Figure 12A**).
- Is there excessive vertical overlap (deep bite)? Lower incisors near the palatal tissue (**Figure 12B**).
- Is there a crossbite of the anterior or posterior teeth? The upper teeth fit inside the lower teeth (**Figures 12C and D**).
- Is there an open bite? The child can stick his/her tongue between the upper and lower front teeth when back teeth are together. This may indicate an underlying habit such as tongue thrust, finger sucking or mouth breathing due to respiratory dysfunctions or blocked airways (enlarged tonsils and adenoids) (**Figure 12E**).
- Is there spacing/crowding between the teeth? Teeth are overlapped and rotated or there are noticeably large gaps between them (**Figures 12F and G**).
- Do the upper and lower midlines coincide? The maxillary and mandibular midlines should be coincident and should both also align with the facial midline (mid-sagittal plane). If the midlines do not coincide, there may be many causes, including impacted teeth, functional mandibular shift, uneven mandibular growth, and midface asymmetries (**Figures 12H and I**).

Close attention to these early warning signs and timely referral to the orthodontist can prevent more complicated later treatments for the patient. Many unfavorable growth patterns may be altered if early treatment is rendered with growth-modification appliances. Arch development with expansion devices can be provided in the early mixed dentition to correct crossbites and relieve crowded arches and in some cases prevent extraction of permanent teeth. Elimination of habits is also significantly more successful and stable if addressed in the early mixed dentition.

Referral for an orthodontic screening at age 7 does not always result in immediate treatment but allows the orthodontist to determine how and when a child's particular problem should be treated for maximum improvement with the least amount of time and expense. Many orthodontic problems will best await treatment until the late mixed dentition or permanent dentition.

Figure 4. A finished orthodontic case, which required extraction of upper bicuspids and a lower incisor, presents with an atypical, yet functionally acceptable, occlusion.

Figure 5A. The first key: molar relationship (courtesy of GAC International).

Figure 5B. The second key: crown angulation (tip).

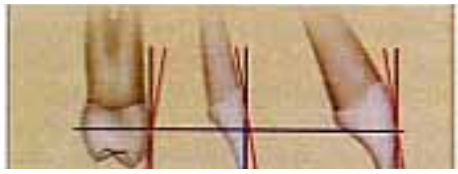

Figure 5C. The third key: crown inclination (torque).

Figure 5D. The fourth key: no rotations.

Figure 5E. The fifth key: no spaces.

Figure 5F. The sixth key: the occlusal plane.

Orthodontic Treatment and Temporomandibular Disorders

Does orthodontic treatment cause temporomandibular dysfunction (TMD)? Is occlusion an etiologic factor in signs and symptoms of TMD? Do occlusal changes created by orthodontic treatment predispose an individual to increased risk for TMD? Several studies have been conducted to answer these questions, but there is still a great deal of controversy. Many studies conducted have suffered from flaws in research technique. This combined with the complexity and the multifactorial nature of TMD has contributed to some uncertainty.

One particular shortcoming is the lack of quantitative information at the condylar level. Most measurement criteria have been based on changes at the occlusal level, either intraorally or with hand-held study casts, or on tomographic assessment of the condyles. Researchers have looked at the tooth end of the mandible and have examined anatomical factors such as molar classification, overjet, overbite, crowding and subjective clinical inspection to determine a correlation with TMD signs and symptoms. Such occlusal characteristics are poor indicators of condylar position.[23-25] Tomography has been shown to be unreliable in evaluating condylar position.[26,27] In most studies that have shown a lack of correlation between occlusion and TMD, no instrumentation has been used to evaluate condylar position as dictated by the occlusion. Conclusions have been based on chin point manipulation, intraoral inspection and hand-held study casts. In a recent study,[28] Crawford showed a reduction in TMD signs and symptoms using a mutually protected occlusal scheme with CR and MI relatively coincidental as measured by condylar position indicator readings.

A review of the literature reveals many opinions on these topics. Most reports suggest the lack of any correlation between occlusion, orthodontic treatment, and TMD. Signs and symptoms of TMD after orthodontic treatment were found to occur in some cases, but no connection was observed between TMJ-related functional disturbances and a well-planned and well-executed orthodontic therapy.[29] Several long-term research studies have indicated that orthodontics is not a cause of TMD.[30-32] Conversely, no data exist to support the notion that orthodontic treatment of children or adults prevents or lowers the risk of subsequently developing TMD.[33] Further, studies have found that orthodontic treatment does not appear to pose an increased risk for development of TMJ sounds or symptoms, regardless of whether extraction or non-extraction treatment has been rendered.[34] Orthodontic patients are not more likely to develop TMD signs and symptoms while undergoing treatment.[35] Post-orthodontic patients have been shown to have no more signs and symptoms of TMD than those with untreated malocclusion or those with normal occlusion.[33] Studies have failed to connect a period of orthodontic treatment to either the onset of TMD or a change in TMD signs and symptoms.[36]

If TMD arises during orthodontic treatment, observation and palliative care should precede irreversible treatment approaches. The onset of pain during treatment will lead the orthodontist to modify active therapy, reduce forces, stop headgear wear, eliminate distalizing forces, minimize or eliminate interarch elastics use, or eliminate gross occlusal interferences by occlusal coverage splint therapy.[33] Patients who present with TMD signs and symptoms, a significant CR/MI shift, or with severe postural habits, may benefit from a period of behavior modification, physical therapy, and even CR-positioning splint therapy before any active orthodontic treatment begins.

Figure 6. Centric relation allows seating of the condyles superiorly and anteriorly within the glenoid fossa (From McNeill C, ed, Science and Practice of Occlusion. Quintessence Publishing, Chicago, 1997, Page 507).

The Importance of Occlusion in Orthodontic Treatment

Can the orthodontist achieve good functional occlusion routinely with orthodontic treatment? Yes, in most cases. Is it easy to achieve? No. Striving for excellence in treating each case to functional ideals is challenging. The goals are excellent functional occlusion, stable tooth position, periodontal health, and a beautiful smile with balanced facial features, but they are not always possible to achieve.

Do ideal occlusion goals apply to the adult patient? Yes, but treatment planning for the adult patient is more complicated and requires input from the patient's dentist and perhaps other specialists. Orthodontists view freeway space in the growing patient as an important ally, allowing changes in the dentition not possible in the adult. The lack of jaw growth in adults means that goals requiring a change in jaw shape or size must involve orthognathic surgery. Adolescents are quite resistant to periodontal damage in the face of patient neglect. Adults are not. However, with careful interdisciplinary planning, remarkable improvements are possible for the adult patient, and ideal occlusion goals need not be set aside.

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Although there are conflicting views on the role of malocclusion as a potential risk factor for TMD,[32,37,38] there are other reasons for orthodontists to be concerned with functional occlusion. Collision of cusps, if allowed to occur, will cause trauma with potential sequela of pulpitis, tooth mobility, attrition, and periodontal breakdown.[39] Muscles can fatigue if the neuromuscular protection mechanism must restrict mandibular movement to avoid cusp collision. Such working and/or balancing interferences during mandibular border movements are also major culprits for significant deviation of MI from CR. Orthodontists want to detect such interferences and eliminate them during orthodontic therapy.

Is an ideal functional orthodontic result stable? If only that were so. Patients have to be told that teeth shift throughout their lives, whether or not there has been orthodontic treatment, and that the changes are typically inconsequential. Orthodontic treatment cannot prevent these changes. Orthodontists try to evaluate the stability of the cases after treatment and make decisions about which patients should indefinitely continue with some sort of retention devices.

Conclusion

As technologic advances in orthodontic therapy have evolved, orthodontists have widened their diagnostic criteria and treatment goals to include an accurate determination of mandibular position and function. The treatment goal of an ideal static occlusion remains important but is now considered only part of a broader view of an ideal final result. An ideal final result will also include the functional criteria of mutually protected occlusion with centric relation closely coincident with maximum

FIGURE 7A. Maximum intercuspation.

FIGURE 7B. Left working, right balancing.

FIGURE 7C. Right working, left balancing.

FIGURE 7D. Left and right protrusive.

FIGURE 8. Hand-held study casts.

FIGURE 9A. Proper manipulation of the mandible to seat the condyles in a superior-anterior direction (From McNeill C, ed, Science and Practice of Occlusion. Quintessence Publishing, Chicago, 1997, Page 507).

FIGURE 9B. Taking a "power centric" relation wax registration.

FIGURE 9C. Study casts mounted in centric relation.

Figure 10a. Determination of CR-MI discrepancy using a condylar position indicator (CPI).

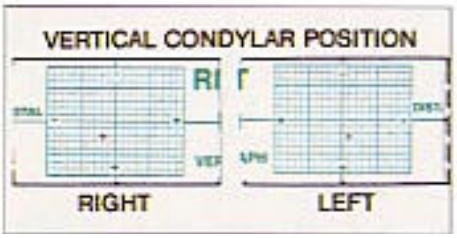

Figure 10b. For this patient, the measurements indicate that when in maximum intercuspation, the right condyle is displaced 2 mm downward and 2 mm backward and the left condyle is displaced 2.5 mm downward and 1 mm backward from their respective centric relation positions. There is very minimal transverse shift between CR and MI.

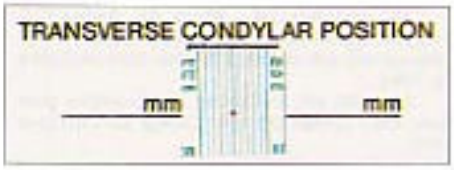

Figure 10c. CR converted lateral cephalogram tracing based on the CPI measurements.

Figure 11. Full arch hard plastic CR repositioning splint (orthotic).

intercuspation. Ideal final results are not always possible. Orthodontic screening by age 7 allows good planning for ideal correction of a malocclusion. Correction of many orthodontic problems in the developing or adolescent dentition is preferable to waiting until the adult dentition. Treatment during this younger period improves the chance of achieving excellent results and better post-treatment stability. In adults, lack of growth and periodontal risk present the orthodontist some diagnostic challenges, but ideal functional occlusion remains a workable goal. The relationship between occlusion and TMD is still unclear. Research has not established a connection, but reliable analysis of

Figure 12a. Excess overjet.

Figure 12b. Deep bite.

Figure 12c. Anterior crossbite.

Figure 12d. Posterior crossbite.

Figure 12e. Anterior open bite.

Figure 12f. Dental spacing.

Figure 12g. Crowding.

Figure 12h. Midline displacement.

Figure 12i. Midline displacement causes blocked canine.

condylar position has not been addressed in such research. Excellent static occlusal goals and functional goals are now understood to be critical elements in long-term stability of orthodontic treatment.

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A Practical Guide to Occlusal Management for the General Practitioner

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ABSTRACT The general dentist has a unique role as the gatekeeper of dental care. In this role, the generalist is called upon to be the primary diagnostician and is charged with the responsibility for triaging patients. Classification systems devised by many of the dental specialties are valuable tools for the diagnosis of diseases and conditions specific to the specialty, but no classifications have been directed to the general dentist. This paper describes a system being used at the University of California at San Francisco School of Dentistry that enables the general dentist to classify a patient's stomatognathic system as either physiologic or nonphysiologic and then guides the clinician toward appropriate treatment decisions.

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Notwithstanding years of research, the role of occlusion in a broad spectrum of diseases still seems to be an area of disagreement, confusion, and misunderstanding.[1-4] Although the give-and-take of experienced academics and clinicians is healthy and will in time lead to a meeting of the minds, in the real world of clinical dentistry, most general dentists would argue that occlusion is a significant consideration in their care of patients. For the clinician, this respect for the subject began in dental school, when, with his or her first placement of a cast occlusal restoration, a significant amount of clinical time was spent adjusting the occlusion to obtain the patient's acceptance of the restoration.

A recent review of experimental occlusal interference studies by Clark and colleagues[5] suggests a reason dental practitioners have a strong regard for the importance of occlusion. When Clark and colleagues assessed studies on the effects of experimentally induced occlusal interferences on the periodontal and pulpal tissues of affected teeth, they found a definite correlation between those interferences and deleterious tissue changes. This suggests that an induced occlusal prematurity will most likely lead to patient discomfort and tissue deterioration. But, they also found these traumatic and inflammatory changes to be transient. In other

words, if a patient can tolerate an artificially induced occlusal prematurity, accommodation is likely to occur. The problem in dental practice is that most patients will not just "stand it," so clinical procedures must be planned to avoid creating an occlusal prematurity or, worse, creating a prematurity to which a patient's stomatognathic system may not accommodate.

The general dentist is unique among dental professionals in his or her responsibility for seeing a diverse population of patients where the assessment of dental health is frequently done as a routine procedure, not associated with specific patient complaints. The chronic nature of the conditions and diseases treated by dentists is akin to beginning a comic strip in the middle, trying to hypothesize what came before, and then predicting the finish. What the general practitioner must do is evaluate signs and symptoms of chronic change of the stomatognathic system and ask the question: Is the stomatognathic system healthy (stable) or unhealthy (unstable). For example, a symptom-free 20-year-old patient with severe attrition of the occlusal surfaces should give more cause for concern than an 80-year-old patient with the same amount of occlusal wear, because a system suffering from premature destruction must be considered unhealthy. Following the discovery phase, the dentist must determine the appropriate care of the system and whether that care is within his or her capabilities. The purpose of this paper is to offer a useful classification system to support the general dentist's evaluation and care of patients.

Existing Classifications

Although classifications have proven to be useful tools in the assessment and management of dental problems in a number of specialty areas, the literature offers little to guide the general practitioner in the assessment and management of occlusion. For example, the Lytle and Skurow classification[6] uses the complexity of periodontal and restorative needs to identify four classes: operative dentistry, crown and bridge, occlusal reconstruction, and periodontal prosthesis. It allows the clinician to determine a restorative class and treatment protocol for the patient. However, differentiation between the classes is based upon the technical difficulty of the anticipated restorations, not on the diagnosis of existing occlusal abnormality.

The popular Angle classification of "malocclusions" is used extensively in orthodontics. This classification is based upon morphological differences between patients. However, when taken in context with other measures of dental health for a given individual, Angle's classes may be found to be physiologically sound. At the University of California at San Francisco School of Dentistry, Angle's classification is considered to be of morphologic variations not malocclusions.[7]

Another classification system, developed by Helkimo,[8] classifies dysfunction of the temporomandibular joint in three types according to the scoring of a dysfunction index with five parameters. The parameters are impaired range of motion, impaired TMJ function, muscle pain, TMJ pain to palpation, and pain upon mandibular movement. This classification is a valuable tool for the assessment of TMD, but it does not address intraoral findings. None of the aforementioned classifications addresses the situation of the general dental practitioner.

A more broadly based system directed toward the general dentist was initially published by Braly[9] in 1972. Braly based his classification on patient data and the need to maintain, modify, or re-establish occlusal stability. The Braly classification system has since been modified, expanded, and incorporated into the teaching program at UCSF to be used as an aid in teaching comprehensive patient care to students of general dentistry. This paper will use a portion of the UCSF Braly-type classification and draw from the clinical experience of the authors in presenting a guide for assessing and managing occlusion in the daily care of general dental patients. It will be divided into three sections: diagnosis, treatment planning, and treatment procedures.

Diagnosis

As health care providers, dentists should all subscribe to the basic logic of patient care: Data acquisition through examination and history must necessarily precede a diagnosis, which in turn must necessarily precede treatment recommendations. Adherence to this simple scheme helps ensure that dentists develop the most appropriate treatment plans for their patients. Yet dentists often place more emphasis on their examination findings and treatment recommendations than on the diagnoses. For example, it is a rare dental chart that has a designated area for diagnoses. And, unlike physicians, dentists are not accustomed to determining and providing the appropriate diagnostic codes to insurance companies for reimbursement of completed procedures. Perhaps this is not surprising when one considers that the diagnoses dentists generally make are, for the most part, unproblematic. The findings that lead to a diagnosis of caries or periodontal disease are usually obvious and rarely suggest competing diagnoses that require careful differential analysis. Occlusion-associated, degenerative processes in the stomatognathic system, however, are not as straightforward. While dentists may all

do a good job of examining the occlusion and recording their findings, it is the next step – making the diagnosis – that often proves troublesome.

Periodontal specialists have provided a good model to diagnose destructive processes and direct appropriate care.[10] The now-standard case-type designations (I-IV) for periodontal disease aid the general dentist in arriving at a diagnosis and possible treatment. Bleeding on probing, increased pocket depth, attachment loss, and other findings now lead to a particular case-type designation based on accepted criteria. Treatment recommendations can then follow logically from a given diagnostic type (e.g., a diagnosis of gingivitis [Case Type I] necessarily excludes root planing from the list of treatment recommendations and necessarily includes oral hygiene instruction).

At the UCSF School of Dentistry, a modified Braly9 classification system is used to establish a "physiologic" or "nonphysiologic" designation for the stomatognathic system in a manner similar to the one used by periodontists. The system designates six Case Types (A-C and I-III) that allow for treatment decisions based upon a thorough evaluation of the stomatognathic system.

Case Types A-C are related to findings for which treatment will not involve the restoration of tooth structure. For example, a Case Type A patient might present with soft tissue pathology such as lichen planus, candida infection, or cancer. For this case type, no restorative procedure is necessary; and the goal of treatment should be to maintain an otherwise physiologic stomatognathic system. A Type B patient might present with occlusal discrepancies causing discomfort in individual teeth for which the treatment might include occlusal adjustment or extraction (such as an unopposed super-erupted third molar). Finally, a Type C patient might present with a severe retrognathic mandible and dysfunctional TMJs requiring complex multidisciplinary evaluation and care.

Case Types I-III are related to findings for which treatment will require dental restorations. Since, at present, general dentistry is primarily restoration-based, this paper's focus has been limited to Case Types I-III.

For purposes of this article, the stomatognathic system is defined as the combination of structures involved in speech; receiving, mastication, and deglutition of food; and parafunctional actions.[11] Evaluation of this system involves both an examination of these structures and an examination of the functional relationship between them. Occlusion is defined as the static relationship between the incising or masticating surfaces of the maxillary or mandibular teeth or tooth analogues.[12] To be designated physiologic, the stomatognathic system must be healthy, stable, and functioning within the expected norms, i.e., no detectable tissue degeneration nor pain in associated structures. To be designated nonphysiologic (unhealthy, unstable), the system must display evidence of past or present unexpected degenerative processes. Findings are the clinical evidence needed to support a diagnosis and, ultimately, treatment decisions.

As described by Stroud,[13] shifts from RCP to ICP found in symptom-free patients are subject to considerable "normal variation" without evidence to suggest an etiology in temporomandibular joint dysfunction. For this classification, a normal shift is described as one for which a causal relationship with clinical findings cannot be found (tooth mobility, fracture, excessive occlusal wear, etc.). The goal for the Case Type I is to avoid affecting the stomatognathic system adversely by whatever restorative or preventive (sealants, etc.) procedure is required as a part of routine dental care. Some would argue this is technically the hardest of the case types to manage (**Figures 1A and B**).

Case Types II and III define a system that is not functioning within the expected norms and is, therefore, termed nonphysiologic (**Figures 2A and B, 3A and B**). Typical findings associated with a nonphysiologic system may include unrestored missing teeth; limited TMJ function; tissue inflammation; pain; tooth hypermobility; a loss or replacement of tooth structure beyond that expected for the age of the patient (e.g., a young patient with extensive caries, multiple root canals, crowns, fixed and removable partial dentures, and/or severe occlusal wear); and an "abnormal" RCP to ICP shift. An "abnormal" shift is defined as one in which a causal relationship with clinical findings such as mobile teeth, tooth fracture, and tooth wear is suspected. Case Type II is distinguished from Case Type III by the absence of TMD or other dysfunctional findings.

Treatment Planning Restorative Procedures

Treatment planning with the goal of maintaining or acquiring a physiologic system requires the perspective that there is not just one restorative material, technique, or procedure that is appropriate for every case type. Each case type must be addressed individually and the materials, techniques, and procedures tailored to the goal for that type.

Case Type I

As described above, the goal in treating the stomatognathic system of a patient diagnosed as a Case Type I is to

render necessary care that will maintain a system found to be functioning in a physiologic fashion. Treatment planned for the Case Type I patient should not alter the physiologic health of the existing system, so the clinician must choose materials and techniques that are least likely to adversely affect the system. As clinicians, however, dentists frequently fail in this regard. For example, it is not uncommon to see as many as four or five different materials (porcelains, resins, alloys, and hybrid materials) used to restore occlusal surfaces and interspersed around a patient's dentition.

One of the best materials for maintaining a physiologic occlusion is gold. Unfortunately, gold is not tooth-colored; and the result is that for the sake of esthetics many young dentitions have been started on the road to destruction with the placement of a highly abrasive feldspathic porcelain restoration.[14-17] Hopefully, the development of new, more physiologic materials with acceptable esthetic properties will result in less destruction.

Case Type II

Once a diagnosis of a nonphysiologic Case Type II has been made, appropriate treatment might include occlusal adjustment, orthodontics, restorations, or other procedures that directly address the causative element in the destructive process. Examples include adjustment of an occlusal prematurity to correct individual tooth mobility, an orthodontic procedure to correct tipping or drifting teeth, a fixed partial denture to stabilize the arches, placement and restoration of implants, or the use of various modalities (occlusal splints, nightguards, biofeedback therapy, etc.) to modify destructive-habit patterns.

The determination that a system is not or has not functioned physiologically

Figure 1a. A Case Type I patient: This 35-year-old patient presents with a complaint of poor anterior bridge esthetics. Clinical evaluation reveals the stomatognathic system to be physiologic. Treatment procedures should, therefore, be directed toward techniques and materials that will maintain the healthy function of the existing system.

Figure 1b. A Case Type I patient: This 42-year-old patient presents with a complaint of pain upon chewing on the left side. Clinical evaluation reveals a fracture of the distolingual cusp of the lower left first molar due to an extensive undermining restoration. Other than this finding, the stomatognathic system is physiologic. Treatment procedures in this case should be directed toward the selection and use of a restorative material that will not compromise the normal physiology of the existing system.

Figure 2a. A Case Type II patient: This 38-year-old patient presents with a complaint of an inability to chew efficiently. Clinical evaluation reveals extensive loss of teeth, loss of alveolar support, large restorations, and an ill-fitting removable partial denture, but no evidence of a dysfunctional craniomandibular relationship. The severity of the oral conditions, however, suggests a nonphysiologic stomatognathic system. Treatment procedures should, therefore, be directed toward modifying the factors contributing to the destructive process.

Figure 2b. A Case Type II patient: This 42-year-old patient presents with a complaint of worn teeth and anterior esthetics. Clinical evaluation reveals heavy attrition and chipping of the anterior teeth, but no evidence of craniofacial pain, TMD, nor other dysfunctional relationship. Treatment procedures should, therefore, be directed toward modifying the factors contributing to the destructive process prior to initiating restorative care.

Figure 3a. A Case Type III patient: This 52-year-old patient presents with a complaint of pain on chewing. Clinical evaluation reveals extensive loss of teeth, drifting and super-eruption of the remaining teeth, deep anterior vertical overlap, and TMJ pain. This patient is diagnosed as having a nonphysiologic dysfunctional stomatognathic system. Treatment must, therefore, be directed toward re-establishing a functional stomatognathic system.

Figure 3b. A Case Type III patient: This 50-year-old patient complains of tipping teeth and an inability to incise. Clinical evaluation reveals a need for multiple restorations but healthy gingival tissues. The lower right posterior teeth are flaring facially, and the posterior bite is opening. Further analysis reveals a severely deviated swallow, suggesting a nonphysiologic dysfunctional stomatognathic system. Treatment for this patient must be directed toward correcting the dysfunctional relationships before restorative procedures can be undertaken.

must lead the clinician to a careful assessment of those factors contributing to the degenerative processes. In addition to the usual patient data, one of the most valuable tools for assessment of the Case Type II patient is an arcon articulator with casts mounted in RCP (a.k.a. centric relation). To hand-hold or mount casts in ICP (a.k.a. centric occlusion) for diagnostic purposes is much like looking out from the home plate of a baseball diamond and not realizing that a lot of the action in the game takes place behind you. The use of casts accurately mounted in RCP allows the diagnostician to evaluate the entire playing field from the backstop. From this perspective, articulated casts can be used to assess the relationship between the dentition and the supporting structures and determine the proper procedures required to correct any degenerative processes a clinician may suspect are associated with the occlusion.[13]

When the degenerative processes have been controlled or corrected, subsequent care of the Case Type II patient can proceed in a fashion similar to the Case Type I patient. The same careful selection of materials, techniques, and procedures is required to maintain the newly acquired relationship.

Case Type III

The most difficult to manage is the Case Type III. This case type has dysfunctional problems plus chronic disease processes that with current knowledge will probably only be managed and not cured. Exceptional diagnostic skills and clinical judgment must be used to determine the proper approach to treatment. Like the complex cancer patient, the Case Type III will likely be treated by a multidisciplinary team. For this reason, the Case Type III is NOT an appropriate patient for treatment in the average general practice and should be referred to an appropriately trained individual capable of managing the necessary multidisciplinary care. Proper treatment might include long-term TMD management, orthodontics and orthognathic surgery, periodontics, fixed or removable prosthodontics, or other complex procedures.

Treatment Procedures

Case Type I

Treating a stomatognathic system that is physiologic without the potential for destabilizing the existing stability is not easy. Direct restorative procedures must be carefully performed to avoid altering the occlusion. Occlusal restorations should be of minimal widths and designed around occlusal contacts. Areas of restored occlusion must be carefully adjusted to ensure simultaneous occlusal contacts that fit properly into the existing system.

Clinicians should use techniques that have the best chance of delivering an accurately fitting restoration. The use of some quadrant techniques and bite registration materials that deliver a restoration in hyper- or hypo-occlusion will allow teeth to drift, result in an altered functional relationship, and potentially destabilize a healthy system. Will the placement of a restoration that is in hyper-occlusion result in a nonphysiologic system? The answer, as cited by Clark and colleagues,[5] is an emphatic "yes," but most systems eventually accommodate to the error. Similarly, a restoration in hypo-occlusion may result in uncontrolled hyper-eruption of opposing teeth and lead to an altered functional relationship.[18]

Indirect quadrant techniques that utilize ICP are best for the Case Type I. Recording an accurate jaw relationship, however, is one of the biggest challenges to indirect restorative techniques. Douglass[19] described two variables that influence the clinician's ability to accurately register interocclusal relationships. Those described were the movement of teeth within their periodontal ligaments that is necessary for any dentulous patient to achieve ICP[20] and the narrowing of the mandible that can occur when the mandible is opened beyond 25 percent of its maximum.[21-23]

The "double-bite" (a.k.a. triple-tray) is an example of a closed-mouth quadrant technique that effectively addresses the variables described by Douglass. First, the teeth are impressed while the patient is closed in ICP, and second, the closed mouth impression decreases the distortion of the mandible that can occur during an open-mouth impression. The advantage of a closed-mouth impression technique is the accuracy of the ICP that can be achieved.

Quadrant techniques utilizing open-mouth impressions and closed-mouth occlusal registrations are subject to serious errors, due not only to the distortions of the casts but also to artifacts inherent in all casts (e.g., bubbles, tears). Numerous materials are available for registering interarch relationships. Among these are wax, acrylic, zinc oxide-eugenol pastes, and elastomeric materials. All materials used to register jaw relationships have problems unique to themselves, but any of these materials used to record a closed-jaw relationship will not accurately fit a cast made from an open-mouth impression. Regardless of how meticulous the technique may be, restorations made with direct or indirect techniques must always be carefully adjusted clinically to avoid creating an occlusal instability.

Table

Clinical Findings, Occlusal Therapy, and Goals for Case Types I, II, and III

Diagnosis	Clinical Findings	Therapy	Goal
Case Type I	**Physiologic** "Normal" RCP to ICP shift No muscle tenderness No excessive tooth mobility/ attrition/abfraction, nor loss of support Stable occlusal contacts Vertical dimension within normal limits for the patient **No TMD:** no inflammation, pain, limited function, or joint degeneration	No occlusal therapy indicated	**Maintain system** Avoid restorative materials and techniques that might alter the health of the system.
Case Type II	**Nonphysiologic** "Abnormal" RCP to ICP shift Unstable occlusal contacts Excessive tooth mobility/ attyrition/abfraction, or loss of support Extensive loss of occlusal surfaces due to caries or defective restoration of tooth structure Missing and/or extruded teeth **No TMD:** no inflammation, pain, limited function, or joint degeneration	Therapy may include: Occlusal equilibration Occlusal restorations Orthodontics Peridontal care Replacement of missing teeth including complete dentures Counseling or other supportive procedures	**Modify system** Alteration of conditions with which degenerative processes can be associated.
Case Type III	**Nonphysiologic** "Abnormal" RCP to ICP shift Vertical dimension altered from normal Unstable occlusal contacts Excessive tooth mobility/attrition Abnormal craniomandibular relationship **Evidence of TMD:** Muscle/TMJ tenderness/pain/inflammation Limited opening/function TMJ degeneration	TMD therapy prior to initiating other necessary procedures Other procedures may include: Periodontal care Altering vertical dimension Occlusal equilibration Repositioning splint Orthodontics Orthognathic surgery Replacement of missing teeth Full-mouth reconstruction Complete dentures Supportive therapies	**Re-establish system** Treatment goals are directed toward long-term management of a severely dysfunctional system.

Case Type II

Treatment of the Case Type II, by definition, requires modification of an unhealthy stomatognathic system. The clinician, therefore, must have a goal toward which to work. McNeill[20] describes the objectives for occlusal treatment as:

- Maximum symmetric distribution of the centric contacts in the intercuspal position;
- Axial or near-axial loading of the teeth;
- Acceptable occlusal plane;
- Guidance contacts allowing for freedom in closing and excursive gliding mandibular movements without deflection; and
- Acceptable vertical dimension of occlusion and interocclusal resting range.

The more extensive procedures generally required in the treatment of diagnostic Case Types II will most likely force the clinician to utilize open-mouth impression, full-arch techniques. But a procedure that utilizes an open-mouth impression is subject to distortions in the casts as described above for quadrant techniques, and, therefore, to an inability to accurately place these casts into occlusal registrations made from teeth that moved while in the process of achieving an ICP.

To best address the limitations inherent in the use of full-arch casts, registrations should be restricted to the prepared teeth and carefully trimmed to limit interarch registrations to very small and strategic areas of the casts. The purpose of an occlusal registration is to stabilize the working cast horizontally and to accurately record the vertical dimension between the arches. Any material that can be trimmed and adjusted to best achieve this purpose for a specific case should be the choice of the clinician.

Achieving the objectives as described by McNeill requires that the clinician consider restoring to an RCP jaw relationship, for it is this relationship that will most predictably achieve the objectives for axial loading and nondeflective contacts.[23] This does not mean that all Case Type II patients should have their dentitions modified to close in an RCP maxillomandibular relationship if treatment goals can otherwise be achieved. As with the Case Type I, procedures must be followed carefully to avoid creating an occlusal prematurity and the potential for destabilizing the system.

Case Type III

The treatment goal for a patient diagnosed as a Case Type III is to re-establish the stability of a severely dysfunctional system. This can be an intimidating experience for an uninitiated clinician. Certainly, novice general practitioners would be well-advised to refer these patients to those with more experience and expertise. Developing the expertise, however, does not require formal graduate programs. Many general practitioners gain valuable experience and expertise through continuing education lectures and interactive study groups.

As the dentist from whom the majority of patients first seek dental care, the general dentist must have the skills to collect data and make a diagnosis and the wisdom to recognize his or her limitations. For the care of patients, and the well-being of the practitioner, it is important the general dentist be able to recognize Case Type III patients and the complexities associated with their care.

Conclusion

The vast majority of adult patients begin their care with a general dentist. As the primary diagnostician, the general practitioner has an enormous responsibility to the patient to properly assess, diagnose, and manage any chronic conditions and/or diseases. When it comes to diagnosing occlusion-related problems, however, few guidelines exist. This article has presented a classification system used at the University of California at San Francisco to assist the general dentist in the diagnosis, treatment planning, and management of problems associated with the stomatognathic system.

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A Breath of Fresh Air

Robert E. Horseman, DDS

Washington, D.C. – The American Geophysical Union warns that ozone depletion, particularly over the Northern Hemisphere, is more severe than had been previously thought. Much of this is attributed to the Senate race in New York.

- *www.oxygentherapy.com* – Air pollution remains a major threat to Americans, contributing substantially to the nation's ill health burden. Scientists expect no improvement in air quality until political air time is severely restricted.
- www.lungusa.com – More than 132 million Americans live in areas that received an "F" for air pollution in an annual report by the American Lung Association. Perrier, progenitor of the bottled water craze, is about to mount a massive ad campaign for its new bottled air product (OxyMoxie), due out this fall.
- Los Angeles – For the first time since record keeping began, Houston's level of ozone concentration exceeded the levels of former champ Los Angeles. L.A. city fathers have vowed to regain the title this summer.
- Detroit – The Detroit News reports that Toronto's O2 Spa Bar is North America's first oxygen bar and quotes Lissa Charron, co-owner, as stating, "Literally, people come here to get a breath of fresh air."

What's going on here? While we in the dental profession have been concentrating on the hazards of biofilm in our waterlines and whether the emergence angle of our veneers is correct, the world has been running out of oxygen, and the ozone layer is thinning and developing holes like a lace doily.

Let's get our priorities right here, people! The Red Cross and various city, county and state emergency agencies have thus far failed to mobilize. The governor has declared no crisis and Rosie O'Donnell has been uncharacteristically mute on the subject. Barbara Walters has yet to interview a single anoxia victim. But without official sanction, enterprising and civic-minded citizens are opening oxygen-dispensing facilities all over the continent.

Dentists -- who, by federal edict,

have oxygen available at all times in their offices -- seemingly have ignored this vital adjunct to their practice for reasons that are not quite clear. Instead, we have blithely glossed over blue-tinged lips and indigo fingernails, incorrectly assuming they were Revlon's new summer hues.

Patients' odd and sometimes eccentric behavior has been diagnosed as postmenopausal, mid-life crisis-oriented, or pure cussedness when the real reason was right before our eyes. Underwater divers readily recognize the phenomenon as "rapture of the deep" or nitrogen narcosis. This condition was heretofore confined to divers going too deep underwater and staying too long.

This is exactly what is happening now on the surface as our O2/nitrogen ratio drops. So says Mr. Ed McCabe (Mr. Oxygen), who can be found endorsing a product called Hydroxygen Plus on the Web. McCabe, who was recently released from 547 days in jail on an unrelated matter, states that the product synergistically combines oxygen, hydrogen, minerals and 34 metabolic and digestive enzymes to alleviate "this problem."

This problem, he says, seems to be that we are simply not getting enough oxygen. Ed confirms that most viruses, parasites, bacteria, fungus and pathogens are anaerobic and therefore cannot live in oxygen. Ed is pretty sure about this and so are a lot of others. Thus, the proliferation of oxygen bars where, for $16 for 20 minutes of refreshment, you can pop in off the street, insert a canula up your nasal passages and "chat, drink juice, relax, whatever."

Ninety-nine percent pure oxygen may appear to be short of the mark to some individuals who are used to nothing but the best. Even Ivory soap is 99 44/100 percent pure. They can be appeased by ordering flavored air -- orange, kiwi or lemon-lime -- as an extra cost upgrade.

Should a customer inhale more than his or her 20-minute limit, become over-euphoric and demand one more whiff for the road, the oxygen barkeep has the same moral obligation to refuse service as a regular liquid-bar attendant. Naturally, designated drivers will soon be the norm for inebriates who experience an oxy-kiwi high, and, inevitably, 12-step programs will have to be formed for oxyholics.

Meanwhile, avant garde dentists are offering the oxygen-deficient public Smile Clinics and Halitosis Centers. Without even a health factor to justify their existence, these enterprises emerge as opportunistic at best. Is this pathetic, or what? We are not suggesting that they be abandoned, important as they are to the economy and national defense, but if dentists are to continue to merit the trust and loyalty of their patients, they must rethink their office air. Biofilm in the water can wait.

Here's what you do: O2 Consulting, which can be found on the Net at www.oxygen4u.com, will aid in setting up an oxygen bar in your office; or, as a sort of getting-your-feet-wet introduction, they will cater an oxygen party for you.

An oxygen party sounds like loads of fun. Matt or Bran of party@oxygen4u.com describe it this way: "You sit next to a large hookah with four sprawling tentacles like an industrial octopus and flasks of water bubbling at the end of each limb. The oxygen'aperitif' comes in orange, mint, or lemon flavors (you can even come away feeling happy, focused, or invigorated by the addition of 'special' aromatherapies). The gaseous cocktail bubbles away as the tubing is wrapped around your ears and put up your nose."

Just the ticket to abort that bloato feeling after a spree among the carbohydrates. As described, this party would seem to be an even greater attraction than the popular sensory deprivation tank soiree.

Exciting as all this is, somebody was bound to pop up with a gloom component. That would be Dr. Norman H. Edleman, medical affairs consultant for the American Lung Association.

"From a purely scientific point of view," he says, "it's hard to substantiate what the benefits could be. Maybe restricted to 20 minutes of consumption, the risks could be minimal, but pure oxygen can be an irritant; taking it could be dangerous to people with severe chronic bronchitis or emphysema." Obviously oxygen can be addictive. Accurate figures on how many people are already dependent on the gas just to make it through their day are not available. It should also be noted that going "cold turkey" is not a recommended treatment modality since addicts seldom live more than 10 minutes upon withdrawal.

You might as well tell patrons of Starbucks that coffee will keep them awake, especially if they drink $16 worth in 20 minutes. There will be those few foot draggers who think 80 cents a minute for something they've been getting for free up till now is excessive. We can only remind them of some of the innovative ideas that have made America what it is today, such as the Tucker automobile; the new, improved Coca Cola; sitcom laugh tracks; and the Nehru jacket.

So dust off that O2 tank in your office that's been waiting for a dental emergency for years. Don't be caught waiting at the post when that first über-hip patient demands a couple liters of the pure stuff, even if it's not a covered benefit.