

Occupational hazards in orthodontics: A review of risks and associated pathology

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The purpose of this article was to review the occupational hazards related to the practice of orthodontics. A systematic approach was used to include all risks involved in an orthodontic practice. The classification of hazards was based on major sources of risks by system or tissue and by orthodontic office area (dental chair, laboratory, sterilization area, x-ray developing area). Potentially hazardous factors relate to the general practice setting; to specific materials and tools that expose the operator to vision and hearing risks; to chemical substances with known allergenic, toxic, or irritating actions; to increased microbial counts and silica particles of the aerosols produced during debonding; to ergonomic considerations that might have an impact on the provider's musculoskeletal system; and to psychological stress with proven undesirable sequelae. The identification and elimination of these risk factors should be incorporated into a standard practice management program as an integral part of orthodontic education. Professional organizations can also assist in informing practitioners of potential hazards and methods to deal with them. (*Am J Orthod Dentofacial Orthop* 2007;132:280-92)

Occupational hazard is defined as a risk accepted as a consequence of a particular occupation.¹ Professionals in dentistry are exposed to many occupational hazards; their effects appear as ailments that affect the dental practitioner and tend to intensify with age. These problems include musculoskeletal conditions due to improper body posture; physical hazards from light, noise, and trauma; biological risks from irradiation and microorganisms; and chemical detrimental sources.

Risk factors for professionals have been studied mainly with survey questionnaires directed to clinicians. However, the results of surveys might apply only to the respondents and are valid at that specific time. Because some professionals do not respond to these surveys, the pool of respondents is biased because the respondents are usually the ones with problems.

In general, the literature lists a limited number of investigations, which confirmed the responders' medical problems by further clinical and laboratory testing. With the exception of Scandinavian countries and North America, where the level of awareness of potential health risks for operators is high, studies dealing with occupational hazards among orthodontists are

scarce. Jacobsen and Hensten-Pettersen² investigated the occupation-related complaints of Norwegian orthodontists relative to data obtained in 1987. Most complaints were skin reactions on the hands and fingers from handling acrylics and bonding materials and from gloves. A few respiratory and systemic reactions were observed. The most recent study found significantly fewer adverse reactions to detergents and soaps, but reactions to biomaterials persisted.³

Similarly, Munskaard et al,⁴ in a survey of Danish dentists, found skin symptoms at a prevalence of 38%, with acrylic resin the key etiological factor. A comparable survey among Swedish dentists found a similar prevalence accompanied with eye and respiratory system reactions; the sources of the adverse effects were cold-curing acrylics and bonding materials.⁵ Recent studies found that methacrylates, natural rubber latex proteins, rubber glove allergens, and glutaraldehyde caused reactions ranging from cell-mediated contact allergy to urticaria and occupational asthma.^{6,7} Sinclair reported that over 40% of dentists had experienced symptoms of hand dermatoses and irritations to eyes, nose, and airway at some point in their practicing lives, and women had twice the odds of experiencing allergy symptoms.⁸ The prevalence of contact allergy to acrylates was below 1% of the responding dentists and, in most cases, did not have serious medical, social, or occupational consequences.⁹ Hand dermatitis experienced by the dental personnel has been attributed to hand washing, occupational exposure to many possible sensitizers, and frequent latex glove use. Although

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Table I. Hazards in orthodontic office by work area

	<i>Respiratory</i>	<i>Musculoskeletal</i>	<i>Hearing</i>	<i>Vision</i>	<i>Skin</i>
Dental chair area	Inhaling of chemicals (composites) Allergens Infection	Neck, shoulder, upper and lower back pain CTS Tendinopathies Repetitive strain injuries	Handpiece noise High volume Suction Ultrasonic scaler	Dry-eye syndrome Maculopathies Cataract Eye trauma Eye strain Infection	Allergy (chemicals) Trauma Infection
Sterilization area	Inhaling of chemicals Allergens Infection	Neck, shoulder, upper and lower back pain	Ultrasonic cleaner	Dry-eye syndrome Eye trauma Chemical burn Infection	Allergy (chemicals) Trauma Infection Burning
Laboratory area	Inhaling of chemicals Allergens Infection	Neck, shoulder, upper and lower back pain CTS Tendinopathies Repetitive strain injuries	Model trimmer Vibrators Low-speed hand-pieces	Dry-eye syndrome Eye trauma Chemical burn Infection	Allergy (chemicals) Trauma Infection Burning
X-ray developer area	Inhaling of chemicals Allergens	Neck, shoulder, upper and lower back pain		Dry eye syndrome Eye trauma Chemical burn Infection	Allergy (chemicals) Trauma

there is a dispute in the literature as to the true frequency of allergic contact dermatitis in dental personnel,¹⁰ extreme caution in handling these substances and close attention to the manufacturer's directions are paramount for diminishing the adverse effects of substances that have not been thoroughly documented in clinical settings.¹¹

The purpose of this article was to review and classify the health risks of practicing orthodontics and associated pathology. Additionally, a guide to the management of hazards in everyday practice is provided, with evidence to increase professionals' awareness of this issue.

CATEGORIES AND SOURCES OF HAZARDS

A general classification of potential operator hazards in orthodontics includes the following.

1. Health hazards impose threats to a person's biological balance from exposure to physical factors (lights, noise, vibration, heat, trauma), chemical irritating or toxic factors (latex, monomers, sterilization and radiology fluid, aerosols during debonding), and biological factors (infections from microorganisms).
2. Other hazards include risks to the professional's well-being, associated with physical or psychological factors such as ergonomic considerations (insufficient or inappropriate equipment, inappropriate work area design) and psychological stress (dealing with patients in general, difficult patients, employees, legal action, and work organization).

Table I categorizes the hazards of orthodontic practice by work area; the **Figure** gives a general classification of the hazards based on the source of risk.

HEALTH HAZARDS

Health hazards for clinical orthodontists include physical factors such as lights, noise, vibration, heat, and trauma.

Lights affect the eyes and vision. Office lighting and dental chair light are critical for optimal working conditions in an orthodontic setting. Additionally, other forms of light are used during daily procedures; the most important is the curing light for polymerization of bonding materials. The hazards associated with various forms of lighting in the orthodontic practice are summarized in **Table II**.

Recently, lasers were introduced in orthodontics for ceramic bracket debonding¹²⁻¹⁴ and cosmetic gingival contouring.¹⁵⁻¹⁷ The hazards associated with laser light range from corneal/lens to retinal damage depending on the wavelength of the beam produced by each appliance.

Eyestrain can also be a problem, due to concentration, insufficient lighting, and inappropriate position of working light in relation to the orthodontist.¹⁸

Maculopathies can be caused by poor lighting. Photoreceptor cells called rods are responsible for peripheral and dim light vision; they receive light and cones, which provide central, bright light, fine detail, and color vision. The photoreceptors convert light into nerve impulses, which are then processed by the retina

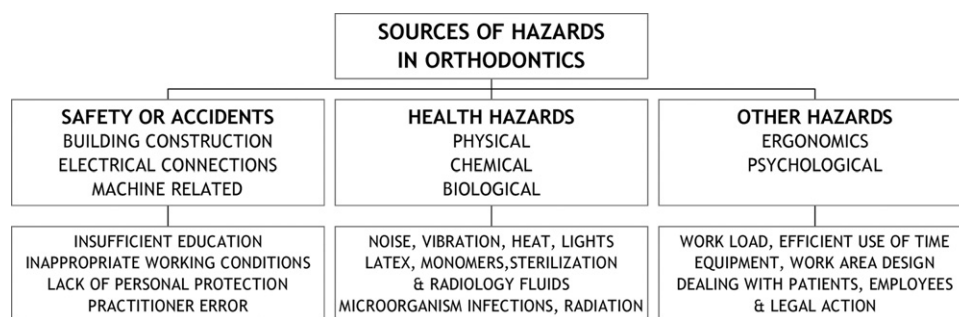


Fig. Taxonomy chart of sources of hazards in orthodontics.

Table II. Hazards related to eyes and vision

<i>Eye strain</i>	<i>Dry-eye syndrome</i>	<i>Maculopathies</i>	<i>Cataract</i>	<i>Allergy</i>	<i>Trauma</i>	<i>Infection</i>	<i>Chemical burns</i>
Concentration	Decreased tear production Increased tear evaporation	Blue-light hazard	Injuries UV lights	Latex glove cornstarch Other	Burs Wire Lab projectiles	Splatter Aerosol contamination Trauma Materials	Radiology and sterilization fluids Disinfectants

and sent through nerve fibers to the brain. Until recently, light sensitivity was believed to depend on the rod and cone photoreceptor cells of retinas. Recent research, however, showed that some of our ganglion cells might perform as a third type of photoreceptor called “intrinsically photosensitive retinal ganglion cells.”^{19,20} These sparsely situated cells are most sensitive to blue light. They seem to exist principally to assist in differentiating between day and night, thus modulating the “sleep/wake” cycles, known as circadian rhythms.²¹⁻²³ When light hits a photoreceptor, the cell bleaches and becomes useless until it recovers through a metabolic process called the “visual cycle.”²⁴ Absorption of blue light, however, has been shown to reverse the process in rodent models. The cell becomes unbleached and responsive again to light before it is ready. This greatly increases the potential for oxidative damage, which leads to a buildup of lipofuscin in the retinal pigment epithelium layer.²⁵ Drusen are then formed from excessive amounts of lipofuscin, hindering the retinal pigment epithelium in its ability to provide nutrients to the photoreceptors, which then wither and die. Drusen are yellow or white deposits in the retina of the eye or on the optic nerve head. The presence of drusen is a common early sign of age-related macular degeneration. Their presence alone does not indicate disease, but it can imply that the eye is at risk for developing more severe age-related macular degeneration. In addition, if the lipofuscin absorbs

blue light in high quantities, it becomes phototoxic; this can lead to oxidative damage to the retinal pigment epithelium and further cell death (apoptosis).²⁶

Blue light is an important element in “natural” lighting, and it can also contribute to our psychological health.²⁷ Research, however, shows that high illumination levels of blue light can be toxic to cellular structures, test animals, and human fetal retinas.²⁸

The eyes of people operating curing lamps are at risk from acute and cumulative effects, mainly due to back reflection of the blue light. Satrom et al²⁹ evaluated 11 curing lights systems that produced visible blue light in the 400 to 500 nm range and found that no unit posed a health risk. A more recent and relevant study, comparing the effects of halogen, plasma, and light-emitting diode units on vision, reported that the exposure time required for plasma and light-emitting diode lamps to achieve curing depth similar to the tungsten-halogen light was longer than the irradiation times recommended by the manufacturers. This is important to know because blue light or ultraviolet (UV) hazard is related to exposure time, and thus requirements for prolonged irradiation can adversely affect vision. Additionally, some plasma units were been found to emit light in the ultraviolet-A region.³⁰

A cataract is a condition with clouding or loss of transparency of the lens. Light transmission through the lens is hindered, and this results in dim, distorted, or blurred images on the retina and decreased vision.

Penetrating injuries (eg, from wire segments or adhesive chips during debonding) and UV light (from photopolymerizing units) are risk factors for cataracts.³¹

Infections can be caused by splashing material, aerosols, and trauma from wires, burs, and other projectiles. Trauma associated with microorganisms could cause various eye infections.³¹

Chemical burns come from acids or alkaline substances. Acids are usually less dangerous than alkalis because they tend to precipitate tissue proteins, which form barriers and inhibit deeper penetration; therefore, lesions are limited to lids, conjunctiva, and cornea. Alkalis saponify lipids in the corneal epithelium and bind to mucoproteins and collagen in the corneal stroma. In this way, they disrupt the normal barriers of the cornea, gain rapid access to the more posterior parts of the eye, and can cause severe eye complications including cataract and secondary glaucoma.³¹ The risk of eye hazards from acids mostly relates to the patient during bonding; additional eye protection such as glasses might be necessary. The presence of alkalis and their potentially hazardous effects can arise from the careless use of disinfectants or other liquid materials sprayed on surfaces or appliances. The operator must use protective eyewear.

Dry-eye syndrome is related to reduced blinking (prolonged concentration), decreased tear production, or increased tear evaporation caused by excessive lighting, heat, or air-conditioning. Symptoms of dry-eye syndrome include irritation, foreign body sensations, stringy mucous, and transient blurred vision. Burning sensation, itching, photophobia, and tired or heavy feeling of the eyelids are less frequently reported.³¹⁻³⁸

Noise

The effects of occupational noise in the orthodontic office can lead to noise-induced hearing loss (NIHL); symptoms can include difficulty with speech communication and other auditory signals, fatigue, and tinnitus. The symptoms of NIHL increase gradually with continual exposure.

The process of hearing begins when sound waves enter the outer ear and reach the middle ear, where the tympanic membrane vibrates and sets the 3 ossicles—malleus, incus, and stapes—into motion. The eardrum and the ossicles amplify the vibrations and send them to the oval window via the stapes. From the oval window, the force moves through the fluid-filled cochlea and stimulates tiny hair cells in the cochlea. Individual hair cells respond to specific sound frequencies, so, depending on the frequency of the sound, only certain hair cells are stimulated. Signals from these hair cells are

Table III. Permissible noise exposure levels (OSHA)

<i>Duration per day (h)</i>	<i>Sound level dB (A) slow response</i>
8	85
6	86
4	88
3	89
2	91
1 ½	92
1	94
½	97
¼ or less	100

Data from OSHA⁴⁰

translated into nerve impulses, which are carried to the brain, via the acoustic nerve, where they are interpreted as a particular sound.

NIHL, currently not treatable, occurs when exposure to harmful sounds causes damage to the tiny hair cells in the cochlea and to the acoustic nerve. The greatest damage is usually caused at 3000 to 6000 Hz. NIHL can be caused by repeated exposure to sounds at various loudness levels, measured in decibels (dB), over an extended time or by a 1-time exposure to an intense sound.

Exposure to noise over a long time can cause a temporary threshold shift, which is a temporary elevation in the hearing threshold that gradually recovers. It might range from a change of a few decibels to a change that temporarily renders the ear severely impaired. A noise-induced permanent threshold shift occurs after a long period of continual exposure to hazardous noise combined with the effects of aging.³⁹ According to the National Institutes of Health, sounds above 85 dB are potentially hazardous. To determine which sounds are hazardous, the frequency and the duration of the sound must be specified. Generally, a noise level of 85 dB (A) in the normal range of hearing, for an 8-hour per day exposure, over a period of years, might be damaging. Sound levels less than 75 dB (A) are considered unlikely to cause permanent hearing loss. DB (A) refers to the decibel scale usually used to measure sound to which people are exposed. Table III shows permissible noise exposures according to the Occupational Safety and Health Administration (OSHA).⁴⁰

Several studies on used and new dental equipment recorded the sound levels of common sources of noise in dentistry; Table IV shows their findings.⁴¹⁻⁴⁴

A possible cause-and-effect relationship between the use of dental equipment and dentists' hearing loss was the aim of several studies.⁴⁵⁻⁴⁸ Results of this research, however, do not provide a definitive answer

Table IV. Noise levels from dental equipment

Device	dB (A)
Air turbine handpiece	65.5-93
Micromotor handpiece	61.9-77
Scaler	73-88
Irrigator	76
Power suction tube	75
Saliva suction tube	73
Ultrasonic scaler	72-81
Gypsum cutting equipment	93.5
Vibrator	98.5
Aspirator and engine	81.7-86.5

as to whether work-related noise impacts dentists' hearing.⁴⁹⁻⁵⁴ The degree of risk might depend on several factors including age, personal susceptibility, total daily exposure, exposure measured over many years, smoking, medication, and noise exposure outside the dental office.⁵⁵

Injuries

Occupational injuries of health professionals are another area of interest, due to the increased awareness of patient-doctor cross contamination. In 1995, a survey sponsored by the American Dental Association⁵⁶ found injuries at a yearly rate of 3.4% among dentists; this agreed with the 3.6% reported by a similar study.^{57,58} Among specialists,⁵⁹ orthodontists had the second lowest prevalence (1.9%) after endodontists (1.3%); pedodontists had 5.5%, prosthodontists 4.5%, and oral surgeons 2.6%.⁵⁶

Bagramian and McNamara⁵⁹ conducted a survey sponsored by the American Association of Orthodontists targeting specifically orthodontists and their staffs. The findings for orthodontists showed a low yearly injury rate of less than 1%, with most incidents occurring extraorally; this is an important finding, since doctor-patient contact during injury is minimal. Most injuries occurred to the index finger and thumb and during wire changes. Other injuries were caused by burs, explorers, rotary disks, scalers, and other sharp instruments. No needle-stick injuries were reported.⁵⁹ Under the same program, McNamara and Bagramian⁶⁰ investigated injuries to orthodontic staff. Their findings showed similar injury rates (1.4% per year) and patterns compared with the orthodontists.

In a study of ocular trauma among orthodontists, it was found that 43% of the respondents reported ocular injuries, mainly during debonding and trimming acrylic.⁶¹ Other procedures included ligating materials, pumicing, and acid etching. Most of the injuries (83.5%) were treated on site without long-term effects. Extra caution

should be used during laboratory procedures, when injuries from projectiles are possible.

Chemical Factors

Chemical factors include latex and associated allergies, monomers, and sterilization and radiology fluids.

Although gloves enhance the barrier abilities of the skin and help decrease cross contamination, adverse reactions to latex are side effects. The general population has a low sensitivity to latex,^{62,63} but in the health care field, due to the continuous exposure to the allergens, sensitivity has been reported to be much higher.⁶⁴⁻⁶⁹ According to OSHA, "Allergy to latex was first recognized in the late 1970s. Since then, it has become a major health concern as an increasing number of people in the workplace are affected. Health care workers exposed to latex gloves or medical products containing latex are especially at risk. It is estimated that 8-12% of health care workers are latex sensitive. Between 1988-1992, the Federal Drug Administration (FDA) received more than 1,000 reports of adverse health effects from exposure to latex, including 15 deaths due to such exposure."⁷⁰

Natural rubber latex, the main ingredient of protective gloves, occurs naturally and is produced from liquid extracts of the *Hevea brasiliensis* tree. From the extract stage until the final product, latex gloves go through a series of processes that introduce into them agents such as benzothiazol, thiuram, and carbamate and other groups with strong allergenic potential.

Immediate allergic reactions to latex can appear in those who have been repeatedly exposed to latex proteins through glove wearing and have developed high levels of IgE antibodies.⁷¹ Clinical signs include rash, rhinitis, edema, bronchospasmus, and allergic shock. Alternatively, allergens absorbed by the skin combine with proteins and form antigens as T cells, and become activated "custom T cells" that circulate in the blood and lymphatic systems. This—the sensitization stage—creates the environment for a more immediate response to these allergens on a future contact with the host. The binding of the custom T cells and the reentering antigen induce immune responses that result in usually localized tissue damage (contact dermatitis). The reaction is usually not life threatening and has a delayed onset. Signs and symptoms include rash, itching, and skin exfoliation. Cornstarch powder on the natural rubber latex gloves, in addition to its role in type I allergy, might also contribute to the development of irritation and type IV allergy.⁷² The prevalence of latex allergy is probably declining because of increased awareness, and a recent study showed that type I

allergy among US dentists decreased from 1996 to 2001 to less than 4%.⁷³

The addition of powders such as cornstarch to simplify glove usage has also been implicated in allergies via dust transportation of allergenic substances. The cornstarch particles, which absorb great quantities of proteins, are widely dispersed in the air, particularly when the gloves are changed. It has been demonstrated that the number of cornstarch particles or natural latex proteins collected in the air of a health care setting can sometimes be up to a hundred times higher than that in a room where only powder-free gloves are used.^{74,75} Two interesting studies evaluated the tendency of cornstarch to bind natural latex proteins; 3 preparations of cornstarch were evaluated for total protein levels⁷⁶ and allergenic protein levels⁷⁷: clean, unused dusting powder; cornstarch exposed to natural latex protein extracts; and cornstarch extracted from powdered gloves. Unexposed cornstarch contained no allergenic proteins, but both natural latex exposed cornstarch preparations had significant amounts of allergenic proteins bound to the particles. The results of both studies clearly demonstrated that cornstarch binds to allergenic proteins, which cannot be detached by simply washing the powder. Adverse reactions to latex occur in significant numbers of dental students and dental practitioners, with those who reported personal and familial atopy more likely to be affected.^{8,78} Studies in the dermatologic literature suggest that glove powders can exacerbate irritant dermatitis and enhance the potential for adverse reactions to other components of natural rubber latex gloves.⁷⁹ Several articles provide direct evidence that natural latex protein allergens, bound to cornstarch particles, are a cause of respiratory allergic reactions and asthma-like attacks.^{80,81}

Synthetic gloves (vinyl, nitrile) were introduced as an alternative for latex-sensitive people. However, they have proven inferior to latex in respect to their capacity to withstand mechanical stress and tactile sensation.⁸² Evaluation of natural latex, synthetic rubber, and synthetic polymeric glove materials showed various degrees of cytotoxicity *in vitro*⁸³; this prompted the introduction of silicone, powder-free gloves.

Allergic contact dermatitis caused by methacrylates is common among dental professionals. Geukens and Goossens⁸⁴ found that 13 of the 31 people diagnosed with contact allergy worked in the dentistry, and Ortengren⁸⁵ found high rates of hand eczema among dentists.

Researchers demonstrated severe cytotoxicity for some monomers used in dentistry,⁸⁶⁻⁸⁹ and glove material permeation by monomers and substantial swell-

ing with structural changes were observed after contact with monomers in relatively short time periods.^{90,91}

Two types of impression dental materials, polyethers and vinyl polysiloxanes, were tested for cytotoxicity, and the polyether materials were found to be more toxic than vinyl polysiloxanes.⁹²

Sterilization and radiology fluids are used to decontaminate or sterilize instruments, surfaces, and impressions contaminated with blood and saliva. Sterilant chemicals include aldehydes, phenols, and quaternary ammonium compounds. These chemicals can cause lung problems and dermatitis.⁹³⁻⁹⁵ Radiology fluids contain chemicals such as ammonium thiosulfate, potassium sulphite, potassium carbonate, hydroquinone, diethylene glycol, acetic acid, and glutaraldehyde. These substances can cause symptoms ranging from skin irritation to allergy and pulmonary edema if mishandled.⁹⁶ Careful handling of fluids, according to the manufacturer's directions, and sufficient ventilation are recommended.

Biologic Factors

Biologic factors include microorganisms and particles. In the dental office, the main source of infection is through interaction of the patient with the health caregiver. This can occur from direct contact with blood, body fluids, secretions, and excretions (except sweat), regardless of blood presence, nonintact skin and mucous membranes regardless of blood presence. A thorough analysis of the infection hazards in dental and orthodontic practices is beyond the scope of this article; this information is provided in standard sterilization-disinfection courses in pre- and postgraduate dental curricula. Infection can occur indirectly by contact with contaminated instruments, surfaces, equipment, and materials. Contact of sensitive body areas with infected droplets expelled from infected persons at short range or inhalation of suspended microorganisms that can survive for long periods can occur in the office environment.⁹⁷ Other possible sources of infectious contamination are dental unit waterlines,⁹⁷⁻¹⁰² handpieces,¹⁰³⁻¹⁰⁸ saliva ejectors and suction, other devices attached to air and waterlines,¹⁰⁹⁻¹¹¹ and radiology equipment (especially digital sensors). Impression materials and orthodontic appliances transported between the clinical area and the laboratory could be a source of infection. Microorganisms are transferred in dental impressions and on dental casts, and certain microorganisms can survive in the cast material for several days. Commissioning laboratory work to an outside facility can transmit microorganisms even farther.¹¹²⁻¹¹⁶ Toroglou et al,^{117,118} in specialty-specific studies, evaluated the contents of aerosols produced during

Table V. Measures to reduce exposure to hazardous materials and procedures

	<i>Respiratory</i>	<i>Musculoskeletal</i>	<i>Hearing</i>	<i>Vision</i>	<i>Skin</i>
Dental chair area	Fresh air access Ventilation Use masks, aspiration during debonding Follow guidelines for infection control	Adopt proper body posture during dental chair work Use ample lighting and in direction that does not produce awkward body posture Arrange intermittent work load Handle instrument properly Use stretching before work	Check noise level of operator	Avoid prolonged concentration and if necessary use assisting appliances Always use protective shield for photopolymerization Use protective eyewear for bonding and debonding (patient and staff also) Avoid splashes during rinsing and spraying	Use powder-free, silicone gloves if irritated by conventional powdered latex Exercise measures suggested by Centers for Disease Control for infection control Cover cuts in exposed body areas (face) to avoid contamination by splashed liquids
Sterilization area	Use ventilation and masks Follow guidelines for infection control	Ergonomically designed area and appropriate bench height Easy access to instruments/equipment	Use insulation for ultrasonic baths	Use protective eyewear	Cover all skin areas (wear long sleeves, gloves, mask)
Laboratory area	Masks, ventilation (preferably fresh air access) Follow guidelines for infection control	Ergonomically designed area and appropriate bench height Adopt proper body posture Easy access to frequently used instruments and equipment Take frequent breaks	Use insulation when possible Use ear plugs during model preparation and trimming	Disinfect impressions Exercise measures as in other areas for eye protection	Avoid contact with methacrylates Use ventilation

debonding procedures in an orthodontic office. They concluded that orthodontists are exposed to high levels of aerosols and contaminants, and that debonding procedures are potentially hazardous to their health. Postexposure management is important to control and avoid further transmission of the infection. Detailed guidelines and information are given in the publication of the Centers for Disease Control and Prevention, "Guidelines for Infection Control in Dental Care Settings—2003."¹¹⁹

The foregoing concerns provoked the investigation of means to minimize bacterial counts in aerosols. Rinsing with antiseptic solutions before treatment was found to significantly reduce the bacterial counts in aerosols during ultrasonic scaling.¹²⁰

Apart from microorganism contamination, a concern was recently expressed on the composition of aerosol produced during the use of rotary instruments. Research indicated that these aerosols contain silica particles from the adhesive resin fillers and various bur material byproducts. The sizes of these particles have been estimated between 2 and 30 μ , thus falling within the hazardous-product particle range of 2.5 μ .¹²¹ The concern about the small size of these particles relates to the fact that they are implicated in many diseases

because they can reach the alveoli. Thus, ventilation, use of masks and aspirators, and mechanical removal of as much resin as possible before using rotary instruments are suggested.

In Table V, precautions and measures to reduce the exposure to hazardous materials and procedures are listed.

OTHER HAZARDS

Musculoskeletal Problems

Dental professionals often develop musculoskeletal problems, which are related to suboptimal work-environment ergonomics that might be responsible for improper sitting postures and movements causing unnecessary musculoskeletal loading, discomfort, and fatigue. Insufficient or inappropriate equipment, inappropriate work-area design, direct injuries, repetitive movements from working with dental instruments, or sitting for extended times with a flexed and twisted back are contributing factors to neck and low-back ailments.^{94,122-124} The limited research in the orthodontic literature showed increased risks for developing these types of pathology.¹²⁴⁻¹²⁷

Musculoskeletal problems happening outside the work environment can either worsen with work or

make work difficult.¹²⁸ Various structures can be affected—muscles, ligaments, tendons, nerves, joints, and supporting structures (intervertebral discs). A number of disorders are included under this category: upper and lower back pain, herniated disc, neck pain with or without cervical root problems, carpal tunnel syndrome, tendinopathies, shoulder pain, rotator cuff tendinopathies, and repetitive strain injuries.

Upper and lower back pain and intervertebral disc disease (acute or chronic) are responsible for work absence in the general population. However, in evaluating absence from work, a differentiation is appropriate between employed and self-employed people, since the latter, often running a single clinician-operated practice, would be reluctant to miss from work for prolonged periods of time.

The dental chair position and the dentist's stool position and orientation relative to that of the patient, combined with the doctor's effort to maintain visibility of the oral environment, result in awkward positions over long periods of time; these in turn result in back problems. The symptoms include low back pain, stiffness, and sciatica with neurological features such as tingling, paresthesia, and muscle weakness.

Intervertebral disc herniation can be just simple bulging, causing pressure to the dura mater and resulting in backache, or it can be true herniation with direct pressure on a nerve root, causing pain, paresthesia, and muscle weakness to the corresponding neurotome. According to the natural history of disc herniation, the affected disc cannot be regenerated to its previous state, resulting in various degrees of loss of disc space and height, stiffness, spondyloarthrosis (spondylosis), and spinal stenosis. This can result in chronic pain (mechanical low back pain) and difficulty in performing various tasks such as bending, lifting, and driving long distances.¹²⁸

Neck problems are associated with a similar etiology, especially awkward body and head posture, which are often required for direct vision into the mouth. The introduction of magnifying loupes is probably the only development over the years that helps dentists keep a more neutral or balanced posture.¹²⁹ The symptoms include intermittent neck pain, often radiating to the shoulders (with stiffness); headaches; tingling, or pins and needles down the arms and fingers, resulting in weakness; and clumsiness. In more severe situations, disc prolapse can occur and, later, degeneration (cervical spondylosis). Because the shoulder muscles are innervated by the brachial plexus, there is also strain on the shoulder muscles (pain, weakness) that will complicate the situation further if there is coexisting rotator cuff pathology.¹³⁰

The rotator cuff of the shoulder consists of the supraspinatus, infraspinatus, subscapularis, and teres minor muscles, which are responsible for abduction, rotation of the shoulder, and stabilization of the humerus head on the glenoid during movement. The most common tendon to be affected is the supraspinatus (tendonitis, partial tear, complete tear, and degeneration). Tendonitis usually causes pain and discomfort that worsens with movements. Tears also cause weakness in abduction; old and degenerative tears cause impingement in the subacromial region (arc pain in abduction, eased beyond 90°-100°). Although direct injuries are rare in dentistry, eccentric loading of the tendon or the muscle and working with the arm in an abducted position for a long time is common. Cervical spondylosis can cause further muscle weakness, which will give rise to more pain exacerbated by radiating pain from nerve root irritation.^{131,132}

Carpal tunnel syndrome (CTS) is the most common nerve entrapment syndrome. It involves entrapment of the median nerve at the level of the wrist. In the work environment, CTS results from rapid, repetitive, and daily use of the hand and fingers for many hours at a time. The problem is compounded when working with a bent wrist, exerting force, working with vibratory tools, and in cold environments. Rapid movement of tendons in the synovial tube causes inflammation and fluid buildup. This can result in atrophy of the thenar muscles; tingling in the thumb, index, middle, and half of the ring finger; night pain; and pain when handling tools.¹³³

Tendinopathies are inflammations of the tendons or the tendon sheaths. The hand performs many complex tasks, and the tendons move inside tendon sheaths with synovial fluid. Repetitive and forceful movements and the use of vibrating tools increase fluid accumulation and inflammation. The affected area is swollen and sensitive to touch, whereas pain is elicited with certain movements such as grasping and pinching. A typical example is the DeQuervain tenosynovitis. This affects the first dorsal compartment of the extensor tendons (extensor pollicis brevis and abductor pollicis longus).¹³⁴ Practically, this translates to difficulty in handling instruments because it affects grasping and rotational and lateral bending of the wrist.

Trigger finger is thickening of the tendon, making it difficult for the tendon to move in and out of the sheath during flexion. The finger can be locked in flexion and requires force to move. Possible causes are degeneration, repeated trauma, or repetitive movements with hand tools.

A solid knowledge of ergonomics, along with

postural exercises, is the key to the prevention of musculoskeletal problems.¹³⁵⁻¹³⁷

Psychological Problems

Mathias et al,¹³⁸ who surveyed American Dental Association members, reporting that 9% had psychological problems, investigated the overall depression rate of dentists. They found that female pedodontists and periodontists were more depressed than their male counterparts, and that only 15% of depressed dentists were seeking treatment, an issue that raises concerns about quality of care. Several studies identified issues related to finances and job growth, time and scheduling, dentist-patient relations, and staff and technical problems as stress sources in dentistry.¹³⁹⁻¹⁴² High levels of occupational stress among dentists are correlated with hypertension,¹⁴³ coronary artery disease,¹⁴⁴ and suicide.^{145,146}

A study of burnout and its causes among dentists in Finland identified psychological fatigue, loss of enjoyment for work, and becoming insensitive toward patients.¹⁴⁷ Comparisons of stress and coping in male and female dentists found that stress levels were similar, although the women experienced more personal and domestic problems. Regarding coping style, both sexes responded similarly in most respects, except that the women were more inclined to discuss their problems.¹⁴⁸ Brand and Chalmers¹⁴² compared stress patterns of dentists of various ages and concluded that older practitioners had less stress than their younger colleagues. However, for some issues related to finance and patient management, both groups were equally affected.

Alcohol use among South Australian dentists was investigated in a study, and the authors concluded that stress and hazardous alcohol consumption were both present, although it can be argued that personal vulnerability factors are much stronger predictors of alcohol consumption than stress or burnout.¹⁴⁹

The dental community has often been portrayed as having a high suicide rate. Although various studies investigated this issue, consensus is lacking. A study that targeted this parameter was undertaken in Norway in 1960 and lasted until 2000.¹⁵⁰ The authors found higher suicide rates among physicians and health care professionals compared with policemen and theologians. Suicide rates were significantly lower in the 1990s than in the 1980s.

Suicide and undetermined deaths for physicians, dentists, registered nurses, attendants in psychiatric care, and auxiliary nurses, were also studied in Sweden after the censuses of 1960, 1970, 1975, and 1980. Male dentists had higher suicide rates after 1960, with

significantly higher suicide rates during the 1970s than the total male working population. A rapid fall in the number of suicides took place from 1981 to 1985. Female dentists had consistently high suicide rates during the 1970s and 1980s. These suicide trends were related to an increase in the proportion of women in the work force and alterations in family patterns in Sweden during the 1970s.¹⁵¹

On reviewing the literature, we concluded that there is little valid evidence that dentists are more prone to suicide than the general population, although data suggest that female dentists might be more vulnerable.¹⁴⁶

According to a report, 20% of dentists on disability were diagnosed with neurological or mental problems, but the percentage of pure psychological problems was not specified.¹⁵² A Swedish study found greater job satisfaction, higher self-confidence, and less anxiety among specialists compared with general dentists.¹⁵³

With respect to the specific anxiety sources, a survey of Canadian orthodontists reported that the highest scoring stressors in terms of severity were patient dissatisfaction with treatment, working with uncooperative patients, and falling behind schedule; these agreed with the results of similar studies of general dental practitioners.^{141,154,155} Stressors such as "causing pain in patients and when the subject proceeds to a difficult operation," which appear among general dentists, were not found in orthodontists. Issues that were more prominent for orthodontics were unrealistic patient expectations, orthodontic relapse, pressure from patients to terminate treatment, general practitioners questioning orthodontic treatment planning or progress, "burn-out" cases, and oral hygiene compliance. When the stressors were evaluated from a frequency perspective, the highest ranked ones were adult patient management, late or no-show patients, and poor elastic or headgear cooperation. When severity and frequency of stressors were combined, time management, broken appliances, and poor oral hygiene and decalcification were the highest-ranking ones. This last classification is important because it represents how the greatest number of survey participants felt about the stressing issues. From the above information, it appears that time management is important in reducing occupational stress. Humphris et al¹⁵⁶ compared the burn-out rates of various specialists and found the lowest rate for orthodontists, assigning their findings to better working environment, more flexibility and control in managing patients, and more cooperative patients because orthodontic treatment is

elective and usually poses no serious threats to a patient's health.

CONCLUSIONS

Contemporary orthodontics involves many potentially hazardous factors related to the general setting of practice; to specific materials and tools that expose the operator to vision and hearing risks; to chemical substances with known allergenic, toxic, or irritating actions; to increased microbial counts and silica particles of the aerosols produced during debonding; to ergonomic considerations that might have an impact on the provider's musculoskeletal system; and to psychological stress with proven undesirable sequelae.

The identification and elimination of the foregoing risk factors should be incorporated in a standard practice management program as an integral part of orthodontic education. Professional organizations can also assist in informing practitioners of potential hazards and methods to deal with them.

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