Ergonomics Applied to Dental Practice

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Library of Congress Cataloging-in-Publication Data

Names: Ortiz Hugues, Juan Carlos, author.
Title: Ergonomics applied to dental practice / Juan Carlos Ortiz Hugues.
Description: Batavia, IL : Quintessence Publishing Co, Inc, [2023] | Includes bibliographical references and index. | Summary: "This book teaches dental professionals how to prevent pain and disorders by adopting the four principles of dental ergonomics: knowledge of body biomechanics, using an ergonomic stool, implementing four-handed dentistry, and working with a surgical microscope"-- Provided by publisher.
Identifiers: LCCN 2022017419 (print) | LCCN 2022017420 (ebook) | ISBN 9781647240905 (paperback) | ISBN 9781647240271 (ebook)
Subjects: MESH: Dentistry | Ergonomics
Classification: LCC RK60.7 (print) | LCC RK60.7 (ebook) | NLM WU 100 | DDC 617.6--dc23/eng/20220805
LC record available at https://lccn.loc.gov/2022017419
LC ebook record available at https://lccn.loc.gov/2022017420

A CIP record for this book is available from the British Library.
ISBN: 978-1-64724-090-5

QUINTESSENCE PUBLISHING
USA

Quintessence Publishing Co, Inc
411 N Raddant Road
Batavia, IL 60510
www.quintpub.com

5 4 3 2 1

Editors: Marieke Z. Swerski and Leah Huffman
Design: Sue Zubek
Production: Angelina Schmelter

Printed in Croatia

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Preface

Through this text, I hope to broaden your understanding of the science of ergonomics and the impact of its practice in clinical dentistry. In my work as an endodontist, I have experienced the transformative nature of an ergonomic practice. When I first started my clinical practice, I used magnifying loupes for several years before making the switch to the optical microscope. Once I started using the microscope, the change in my posture was almost immediate. This inspired me to learn more about ergonomics and create a practice that was organized, efficient, healthy, and truly oriented to excellence. As I became certified in all levels of both occupational and dental ergonomics, I was able to improve all the details within the office. Not only did I incorporate the microscope, chairs, and other equipment, but I also made substantial changes in the management of clinic staff and patient care. As I acquired and applied this knowledge, I found that pain in my arms and body became reduced and eventually went away.

I began to travel, visiting clinics throughout the United States and Latin America, and saw that ergonomic principles were not being taught in dental school and therefore not applied in practice. Clinicians lacked the knowledge of proper posture, positioning, and organization, and as a result they were setting themselves up for future pain and disorders. The high incidence and prevalence of musculoskeletal disorders in dentistry is no secret, and pain often becomes part of the lifestyle. But it doesn't have to. Understanding the physiology, anatomy, biomechanics, and anthropometric factors that go into designing and organizing an office, as well as the psychosocial and administrative factors, can put you on the right track to address—and even prevent—these disorders. Even better, if these concepts can be applied starting in dental school, dentists can learn correct habits from the start, thereby ensuring a healthy, efficient workflow for the rest of their career.

Ergonomics is a multidisciplinary science that seeks to determine the intellectual, conceptual, and physical changes needed within an office. Throughout this book, you will learn what ergonomics is and why it matters, the most frequent and painful syndromes associated with poor ergonomics, proper postures to prevent these syndromes, and the tools and modifications necessary to build an ergonomic office. The goal is to lay the groundwork for dentists and students to make the changes necessary to prevent musculoskeletal disorders within our profession.

Acknowledgments

I would like to thank all the people who, in one way or another, have contributed to my academic and professional growth throughout my career.

To my parents for sowing the seeds of hard and disciplined work, who through example set me on the path of honesty, perseverance, and a desire to seek education—the most worthy means to grow from the inside out.

To my lovely wife, Susana, who enlivens my life with her love and support.

To my daughter, Mei Helena, who is a fuel in my life to keep working hard with passion.

To all the university professors from my undergraduate degree at the Universidad Latina de Costa Rica, and to all those who trained me as a specialist in endodontics at the Maimónides University of Buenos Aires, Argentina.

To the professionals from all over the world who have guided me with the example of excellence.

To the Academy of Microscope Enhanced Dentistry, which has allowed me to meet brilliant minds, humble and hungry to spread knowledge from the most sincere desire for solidarity and development of other colleagues.

I fell in love with the surgical optical microscope when I first saw it in Dr Santiago Di Natale's office in Buenos Aires, Argentina, in 2006. Finding this precise and excellent technology sparked my passion for the profession. It strengthened my faculties as a clinician; I was able to develop my specialty to its maximum potential, and it makes me perform my work responsibly and with certainty.

To the Palmieri Family, who within the Newton SRL Industria Argentina microscope manufacturer-client relationship found a family. Together we have fed each other ideas, projects, and continuous evolution, based within the framework of a great friendship.

I understand life as an eternal school, where we come to learn and we leave without learning everything, because knowledge is infinite. This book is just a compilation of all my years of study, as well as the study done by many others who were interested in generating knowledge on the beautiful topic of ergonomics. There is a saying: "You can get there faster, but accompanied you can go further."

Introduction

For the dental worker, putting into practice everything mentioned in this text would be a very smart way to improve their quality of life and to succeed in their work. Few texts in the academic area touch on ergonomics and how it directly impacts health and efficiency. The dentist works long hours in awkward and static postures, performing multiple repetitive movements. Their responsibilities are many, and precision is necessary for success.

Knowing what kinds of equipment industries sell and recognizing their shortcomings will go a long way in helping you modify equipment to improve ergonomics. It is essential to recognize the postural and positioning errors that are made daily. This is the only way to correct them and prevent musculoskeletal disorders, which can cause pain and even incapacitate the dentist or dental staff. This entails serious problems—not only physical, but also financial, because pain prevents the dentist from doing a good job, and a day without work is a day without profit in this profession.

It is amazing how simply learning to sit correctly and what positions the human body is designed for can make all the difference. It should be emphasized that the operator's stool is the most important piece of furniture to invest in, because the dentist spends more time in contact with it than with any other element in daily life. Therefore, the stool constitutes the starting point for good ergonomics while working.

Prevention is the best way to guarantee longevity. Therefore, it is crucial to plan time and space for breaks and stretching. Also, the incorporation of the surgical microscope is of utmost importance—there is no other technology that, in a single act, improves the visual capacity and posture of the user. Knowledge of this tool, its settings, and its proper use to enhance ergonomics is extremely important. Training in the use of the microscope in dentistry and its subsequent use in daily practice should be a priority.

The importance of training the assistant should be emphasized as well so the operator can work with their eyes in the microscope and thus eliminate unnecessary movements, increasing productivity and focus on the operative field. Furthermore, it is crucial to consider the assistant's position to prevent them from experiencing the same musculoskeletal pain to which dentists are exposed. They should respect the same prevention laws as the dentist, as these directly influence the efficient workflow that all professionals want in their practice.

With this text, I hope to guide many colleagues to understand why we are a profession with a high risk of musculoskeletal injury. Only with this understanding can we succeed in preventing these disorders and make the necessary corrections that allow for painless and quality work.

General Aspects of Applied Ergonomics

1

Background of Ergonomics

Definitions

There are currently several definitions for this science. According to the Occupational Safety and Health Administration of the United States (OSHA), *ergonomics* can be defined as the study of work. More specifically, it is the science that deals with adapting work to the worker, rather than physically forcing the worker's body to fit the job. It can also be defined as the development and application of a human-system interface that is responsible for the interactions between the human and other elements of a system, such as hardware, software, environment, work, organizational structure, and processes.[1]

Ergonomics and *human factors* are two scientific disciplines that have the common objective of minimizing the risks of injury and disease by optimizing human well-being and creating the holistic conditions for the worker to perform the work efficiently and well. The difference between the two terms is that ergonomics addresses the physical aspect of work and human factors addresses the psychologic aspect.[2]

History

Ergonomics is the integration of a number of diverse scientific disciplines, including physiology, biomechanics, psychology, anthropometry, industrial hygiene, and kinesiology, among others.[3] This science studies musculoskeletal health and its effect on worker performance.[4] With the Industrial Revolution, our society shifted from one based on manual/agricultural production to one based on industry. Accompanying this change was a shift of work from active and dynamic tasks to sedentary tasks thanks to innovations such as machine and computer power.

The momentum of ergonomic advances was due to people such as Bernadino Ramazzini, better known as the father of occupational medicine, who

Chapter objectives

- **Learn the history of ergonomics and concepts of work enhancement**
- **Understand the importance of ergonomics in work processes within dental practice**
- **Address ergonomic risks in dentistry**
- **Address benefits of applied ergonomics within dental practice**
- **Understand applied body biomechanics in dentistry**
- **Understand anthropometric factors in the design of equipment used**
- **Apply ergonomic interventions to avoid musculoskeletal risk factors**

studied medicine with a particular interest in occupational diseases. He was the first to correlate work activities with musculoskeletal disorders. Another contributor to the development of ergonomics as a field was Frederick Taylor, who applied principles of science to improve work efficiency (ie, the scientific study of work). Over the years, countless inventions and concepts have been developed to modernize processes, make them more efficient, and improve the quality of life of the worker.[5]

Since the Industrial Revolution, new ways of working have been imposed in the different societies of the world, accompanied to a great extent by technologic advances that have produced transformation and disruption in the entire labor market. Sedentary work has increased by 83% since 1950, and almost half of the jobs in the United States are currently performed in a sedentary manner.[6]

Applied Dental Ergonomics

Risks in dentistry

More than 70% of dental students complain of musculoskeletal pain in their third year.

Numerous studies have been conducted on the prevalence of pain related to work in dentistry, and the results indicate that more than half of dental professionals experience some form of pain. This pain normally starts as early as dental school (or dental hygiene school), creating bad habits that promote a continuation of the problems throughout one's career. More than 70% of dental students complain of musculoskeletal pain in their third year.[7] Most musculoskeletal disorders are therefore inherited from years of ignorance and lack of training in ergonomics, which is why it is essential to recognize the benefits of an ergonomic dental practice in the early stages of training programs. Bad habits practiced for many years are difficult to eradicate; however, when we learn correctly, we create good habits from the beginning.

In dentistry, it is very common to develop bad posture. Many dentists focus first on the patient's comfort rather than that of the operator or the work team, which is not the best way to avoid work-related risks. Unfortunately, over time, these bad postures can cause some of the most common musculoskeletal disorders. According to the European Agency for Safety and Health at Work, if it is assumed that poor posture in the workplace is the initial factor or symptom developer at the musculoskeletal level, then these disorders are considered *work-related musculoskeletal disorders*.[8]

It is important to use ergonomically designed equipment because this technology can minimize risk factors for developing musculoskeletal disorders.[9] When building a dental office from the ground up, the ideal situation is to achieve harmony between furniture, dental equipment, technologies, space management, safety training, and prevention of musculoskeletal risks. Unfortunately, this is the exception, and many times we start working in places without space design or ergonomic criteria, for which modifications have to be made to achieve some degree of improvement in the ergonomic operation of the office. In this case, we must analyze what is adjustable, what can be redesigned, what must be moved, and what must be purchased or invested in to modify the nonergonomic and transform it to ergonomic.

Benefits of ergonomics

Implementing ergonomics and techniques for prevention of injuries in the field of dentistry can have a profound impact on professionals, including the following[10]:

- Improved management and reduction of musculoskeletal pain
- Prevention of work-related injuries
- Increased productivity
- Reduction of stress at work
- Decreased employee turnover
- Decreased number of sick days
- Safer work environment
- Increased quality of life and job satisfaction
- Increased career longevity

Dental health care workers (dentists, assistants, hygienists) are predisposed to muscle imbalances and the resulting cascade of events. When dentists and their staff are forced to work above their physical limits, a spiral of poor performance begins, and accidents occur more frequently. This results in an increase in operating costs, including the hiring and training of new staff, increased medical costs, and worker's compensation. To avoid the vicious cycle of musculoskeletal disorders, dental professionals must take these risks seriously and take effective action throughout their career.[7] If the dental staff and dentist ignore these consequences due to ignorance or neglect of ergonomic principles, there will be a risk of injury. Ergonomics is designed to minimize worker fatigue and reduce musculoskeletal stress through balanced neutral postures, control of working time movements, and provision and maintenance of healthy work environments. An ergonomic dental practice means an increase in productivity and a decrease of injury risk, which is the main objective of ergonomics.[11]

OSHA proposes standards that can be applied to any occupation and provides basic information on musculoskeletal health and safety; it is a simple guide to understand work standards, which in the same way can be applied to our profession.[7] Because ergonomics is multifactorial, risk factors must be controlled when creating ergonomic intervention programs in any work practice. There are three ergonomic controls as described in Table 1-1. The preferred method to ergonomically control the risk factors is with engineering control because it produces more permanent and efficient results; however, it is also the most expensive method.[12]

Control of work practices, on the other hand, focuses on the way work is developed. In this way, procedures and practices are modified to ensure neutral work positions and safe techniques. To obtain the best possible result, it is necessary to create an ergonomic work protocol in which *(1)* the work environment (what we use to work), *(2)* the task being performed, and *(3)* the focus on the comfort of the operator who performs the work are integrated. This will guarantee an efficient workflow that favors the health of the body parts of the professionals involved (Fig 1-1).

TABLE 1-1 Ergonomic controls

Type of control	General examples	Dental examples
Administrative control	▪ Equipment maintenance ▪ Job rotation ▪ Rest times	▪ Organization of agenda ▪ Distribution of procedures ▪ Rest time scheduled with and between patients
Engineering control	▪ Workstations and work areas ▪ Materials and objects and how these are handled ▪ Office equipment	▪ Office counter ▪ Surgical microscope ▪ Dental chair delivery system ▪ Ergonomic operator stool ▪ Physical space ▪ Horizontal distances to instruments and tools
Control of work practices	▪ Focus on the way work is developed ▪ Modification of procedures ▪ Safe working postures ▪ "Ergo breaks"	▪ Four-handed dentistry ▪ Seated work ▪ Postural education ▪ Transfer of instruments

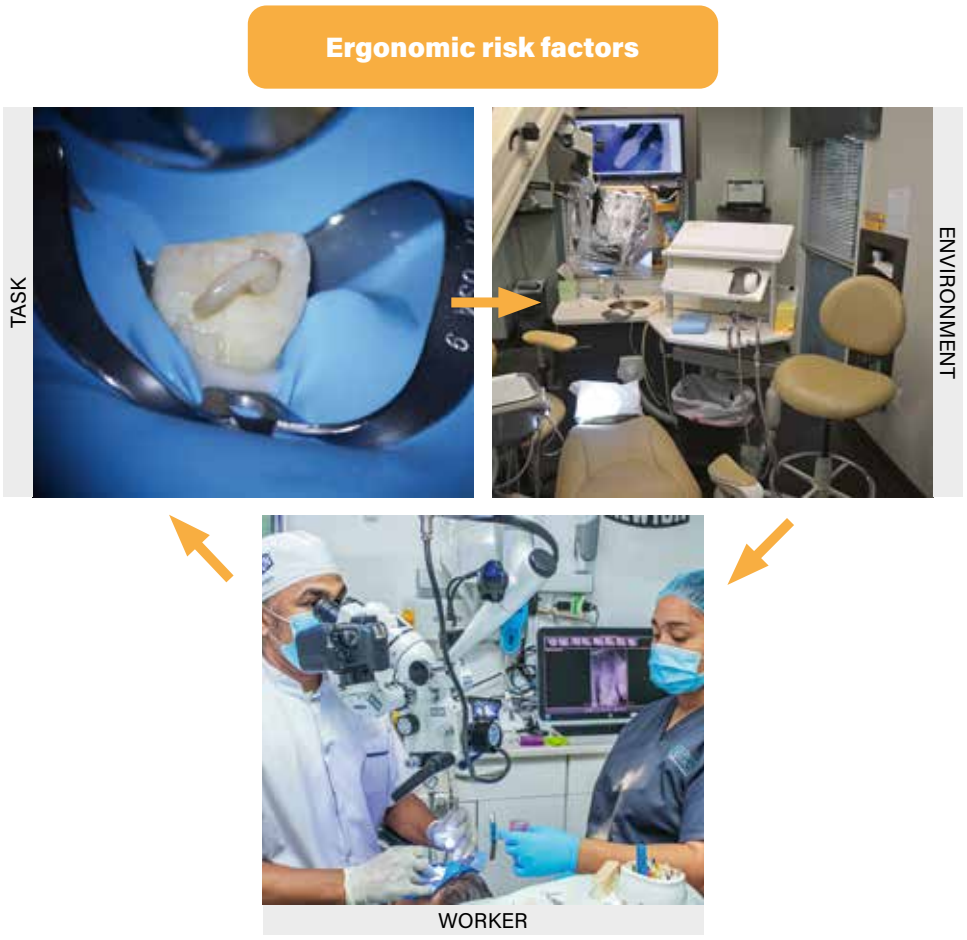

FIG 1-1 Integration of task, worker, and environment.

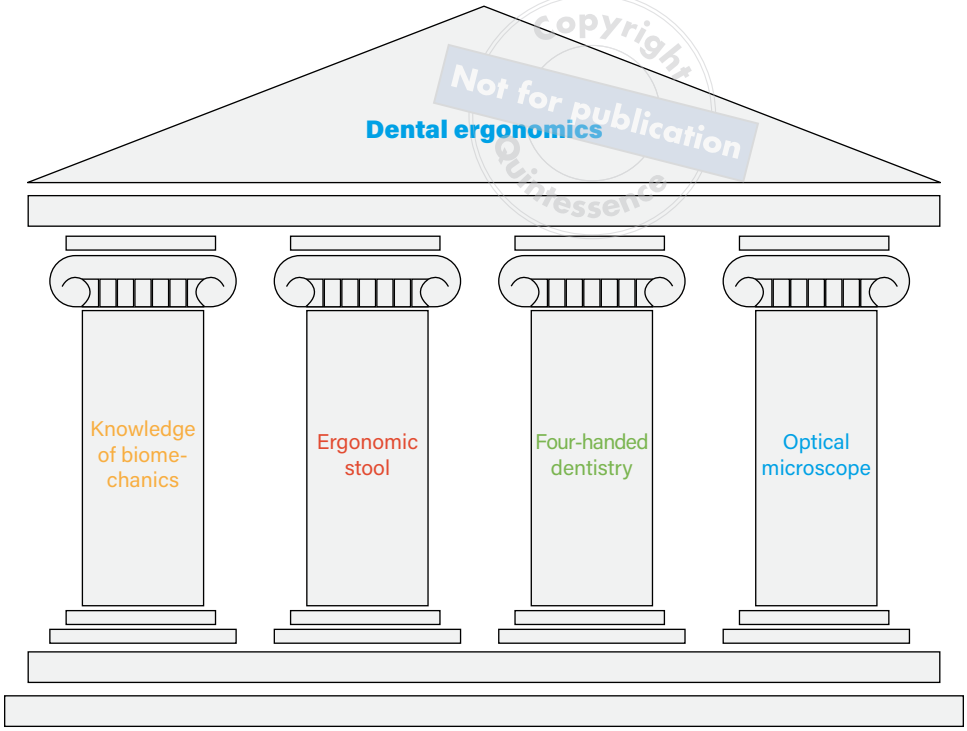

FIG 1-2 The foundations of dental ergonomics include knowledge of biomechanics, an ergonomic stool, four-handed dentistry, and an optical microscope. Without all four pillars, the support is not adequate.

Foundations of dental ergonomics

Much of the information in this book is based on the experience and result of a broad scientific search on how to improve my own dental practice. In the process, I identified four foundations of ergonomics as applied to dental practice:

- Knowledge of body biomechanics
- Ergonomic operator's stool
- Four-handed dentistry
- Surgical optical microscope

The integration of these four foundations within our clinical practice (Fig 1-2) will make our profession one that is productive, simplified, and efficiency-oriented. The key to ergonomic success and the maintenance of healthy systems within our offices is to rely on all four foundations; a deficiency of just one of these prevents the office from being truly ergonomic.

Biomechanics of Posture

Dental work is designed to be carried out in a sitting position, with the dentist remaining sedentary for long working hours. From a biomechanical point of view, this is no different from an office worker; people who work in an office spend approximately 89% of their working time sitting, increasing the risk of developing

pathologies such as obesity, high blood pressure, increased cholesterol levels, and heart disease.[13]

In a comprehensive approach to ergonomics, a knowledge of occupational biomechanics is essential to understand the behavior and function of the human body. In this specific case, anthropometrics is a fundamental concept, because dentists often work with equipment, instruments, and technologies that must be selected according to individual anthropometric parameters and physiology. Dentistry is a job with an important physical component, so recognizing the anatomy and physiology of body parts can help us understand the risks of different situations in our profession.

Occupational biomechanics studies the movements and the effects of the forces on objects, applied to living systems within work environments. These forces include gravity, external loads and resistances, and internal forces that act on the skeleton, on the muscles, and in other tissues while performing a job. Ergonomists use their knowledge of biomechanics to understand and improve conditions that may currently be challenging in a work environment.[14]

Personally, when conducting ergonomic assessments and consults in dental offices and dental schools, I refer to the biomechanics of the human body as the missing link within the chain of ergonomics—it is not taught in dentistry. The lack of information and application of clear and simple concepts of ergonomics has a long-term impact on the professional lives of students, and beginning their careers with this knowledge in hand could be very beneficial to their health.

Two of the most important biomechanics concepts in this book are *posture* and *positioning*. It is essential to understand body biomechanics in order to apply ergonomics at work. In a profession such as dentistry in which the worker is seated for long hours in awkward positions (ie, improper posture and positioning), injuries can occur over time.

Biomechanics is taken very seriously in other professions that require mental and physical demand, where performance depends on the state of proper use of the human body. For example, athletes train and stretch methodically with specialized equipment to prevent injury and result in peak performance; dentists should treat their profession in the same way. After all, the goals are the same: to avoid injuries and to perform the work to a high standard in the long term without pain. Mental and bodily fatigue—and of course pain—will restrict the performance of any job.[15]

Mental and bodily fatigue—and of course pain—will restrict the performance of any job.

The discipline of ergonomics teaches us the proper way to use our bodies in dentistry. As we incorporate this knowledge, we will learn to avoid the cycles of poor posture and positioning to which dentists, hygienists, and assistants are subjected. Becoming aware of how the various body parts move, rest, and position themselves during long working hours is a starting point to prevent musculoskeletal disorders and irreversible injuries. In a profession where the worker is seated for long hours, such as dentistry, a proper understanding of the biomechanics of the human body should raise questions such as the following:

- How do I move my different body parts during dental work?
- How many times do I execute and repeat the same movements?
- Am I aware of the neutral sitting posture?
- How am I using my equipment according to my physical parameters?

Asking these simple questions could point to the origin of many of the musculoskeletal pains to which dentists are subjected (which are generally the result of a lack of understanding about how the body really works biomechanically). To result in a healthy long-term outcome, the biology of the body should be respected, and integrated work protocols, technologies, and equipment should be designed for ergonomic purposes.

Kinetics and kinematics

Kinetics and kinematics are two areas of biomechanics that name, evaluate, measure, and study the movement of the components of the body in a state of rest (static) or in movement. Kinetics examines the forces acting on the body during movement as well as the motion with respect to time and forces. These forces include gravity, muscles, friction, and external resistance.

One example of a typical procedure in general dentistry is removing a caries lesion to later place a composite restoration. This procedure may be done using the naked eye or loupes, possibly without an assistant, and may take 1 hour or more depending on the size of the lesion. To perform the procedure, the operator must repeatedly perform multiple motions such as turning the head to the left; tilting to the side, forward, and down to focus on the tooth; moving the upper extremities to reach instruments; rotating the trunk sideways to pick up and put down equipment and tools; and more. At the biomechanical level, the muscles and tendons are working all the time to maintain the neutral posture of the body during the procedure. The motions create internal stress and transmit loads and pressure between adjacent structures within or around a joint at the fulcrum points. The internal forces that are generated in the muscles produce voluntary movements. The efforts and loads necessary to complete the task are transmitted from the muscles to the tendons, ligaments, and bones as well as torque (forces) on the axial axes of rotation in the joints, tension, compression, torsion, or shear within the anatomical structures of the body.[16]

Specifically for the task of caries removal and restoration placement with the naked eye or loupes without an assistant, biomechanically, the internal forces are generated by the musculoskeletal components to keep the operator's head raised and aligned with the spine. Then there are forces (torque) on the axial axes of rotation in the joints or fulcrum points, such as the cervical and lumbar from where the inclination is made to see in the patient's mouth, and the movements from the shoulder joints outward and up to reach. These different inputs, frequently used for this type of activity, do not result in the best use of the operator's body.

The joints and bones behave a certain way when moving the limbs, head, and back according to the axis of movement, axis of rotation in the joint, and the degree

of freedom of each joint. Motions create internal stress by *(1)* imposing loads on the involved muscles and tendons in order to maintain the position, *(2)* transmitting loads to underlying nerves and blood vessels, and *(3)* creating pressure between adjacent structures within or around a joint. Dentistry places the operator and staff in working positions with the head forward and down, with movements or esthetic postures that place the joints, muscles, and bones in situations of cyclical fatigue. Positioning like this day after day adds to the potential health issues.

Gravity

Let's address the fundamental force that acts on all body segments all the time: gravity. When they are in direct contact with a surface (eg, in the sitting position), no forces are needed by muscles or ligaments to maintain the position of certain body parts. The surface of the support structure (floor, chair, back, armrest, etc) provides the required equal and opposite "reaction" so that movement does not happen.[17] When there is no support structure, the body must exert force. For example, an endodontist must elevate their elbow over the shoulder at different angulations in the process of shaping root canals in molars. This is a repetitive and sustained posture, and in addition to the internal muscular forces and torque in the shoulder joint, the gravity forces remain, exerting forces on the extremity down and close to the trunk. Similarly with the shoulder, the thrust of gravity on the entire arm is usually passively opposed by the tissues of the joint. This can explain why working with the shoulder elevated or abducted—or even sitting on a stool with no armrest—may increase the possibility of pain and discomfort in the neck, shoulder, and arm.

Statics

Dentistry places the body in prolonged static postures, and this is one of the most dominant risk factors in the profession. *Statics*, a subdivision of kinetics, is the study of bodies when they are at rest and all forces are in equilibrium. The statics of the body are investigated by first reviewing forces, torques, and equilibrium and then applying these conditions to statics in a plane or lever. The principle that governs all static conditions, including static human postures, is that the sum of all forces in any direction (in this case, the vertical—gravity) must be zero. This means that there can be any number of forces acting in the body segment, but these have to sum to zero, with the forces up matching the forces down.

There are several types of forces applied on the body tissues (bones, ligaments, and tendons; Fig 1-3):

- *Compression:* Equal and opposite load directed toward the surface
- *Tension (tensile stress):* Equal and opposite load directed away (outward) from the surface
- *Bending:* Tension and compression applied at opposite sides of a surface
- *Shear:* Load directed parallel to the surface
- *Torsion:* Shear applied along a surface, causing torque

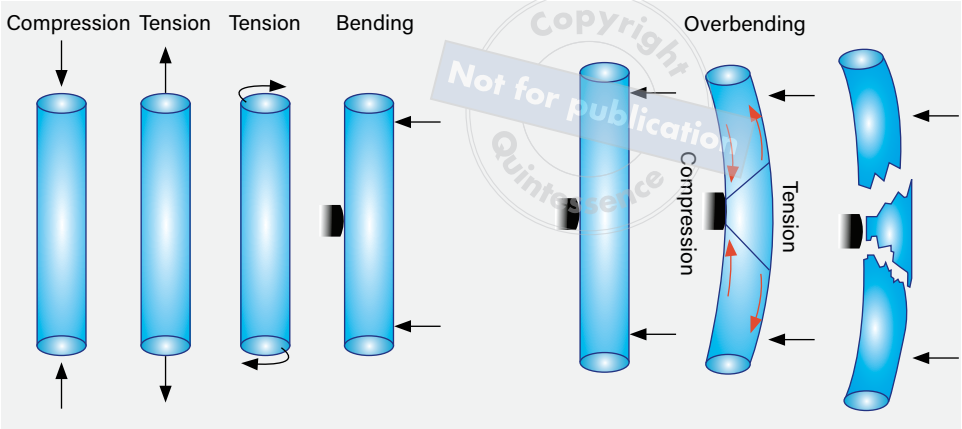

FIG 1-3 Applied forces acting on body tissues.

The way in which these forces are applied externally in static postures will generate an internal force effect on muscles, tendons, ligaments, and joints as a reaction. Examples include shaping a dental canal with the dominant hand, suturing soft tissue, placing layers of composite, preparing a tooth for a veneer, grasping a mirror with the nondominant hand statically prolonged, and tilting the head down to focus on the tooth for minutes or even hours. In addition to these linear support situations, any posture requires an active muscular effort to maintain it. Depending on the posture, the forces can be considerable, and they are regularly accompanied by some unwanted but physiologically unavoidable consequences.

When gravity does not act exactly on the center of a joint, as is generally the case, there is a tendency to rotation (moment or torque) on the axial axis of the joint. The moment and magnitude created in the joint when working will depend on the force and the perpendicular distance from the axial axis of rotation. For example, bending the head forward from the cervical spine is not the same as bending forward from the lumbar spine. The further the line of action of the force of gravity is found from the center of the joint, the greater the moment caused by the gravity. In the case of static posture, when there is no movement, the biomechanical law is applied: The moments that tend to cause rotation on the joint in one direction (clockwise) must be exactly counterbalanced by moments that tend to cause rotation of the joint in the opposite direction (counterclockwise). Leverage is everything. Following the same example, to maintain an upright position when leaning forward from the lumbar spine, torque is counteracted by tension in the back extensor muscles (Fig 1-4). It is easy to understand the nature of musculoskeletal pain in these areas, which will be described in later chapters. To summarize, the effect of postural deviation and the internal forces to sustain the posture combined with the gravitational forces place the different body parts in risk situations. This occurs even if no extra weight is carried on the limbs and is exacerbated when modifying factors (eg, duration, frequency, intensity) are present.

Leverage is everything.

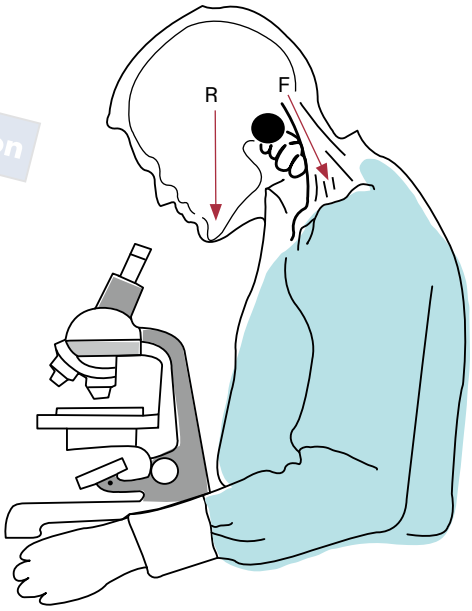

FIG 1-4 *(left)* Applied forces acting on body tissues during naked-eye dentistry include forward head and lower back posture.

FIG 1-5 *(right)* Static head and neck posture. R = resistance; F = force.

An example of static head and neck posture associated with forward head posture and leverage is when the force of gravity acts in the center of the mass of the head (Fig 1-5). Here, we assume that the axial rotation axis or fulcrum is the atlanto-occipital joint between the head and the first cervical vertebra, the force of control of which is provided by the muscles of the back of the neck. The moment for clockwise rotation is the distance from the thrust line of the muscular force to the axial axis of rotation (lever). In static posture, these two moments must sum to zero. For example, if we estimate that a person's head represents 7% of their body mass, the gravitational force of a 68-kg (150-lb) person is 4.76 kg and, consequently, the force provided for the muscles of the cervical spine should be approximately 9.5 kg. It is important to note that the forces act in the downward direction on the first cervical vertebra.

The compressive strength in the atlantooccipital joint is not just the weight of the head but approximately three times that amount in a forward head posture. In the forward head posture example, if the user leans forward more than 25 degrees, the resistance of the lever increases. As a result, an increase in muscular effort is required, as well as a proportional increase in the compression of the joint. Conversely, if the posture is more erect, the muscle strain and compression in the joint is smaller. The same biomechanical principle applies to the posture of any segment of the body that is not in a relaxed vertical alignment, such as your lower back and shoulder-arm. In this case, we assume that gravity acts on the combined head-arms-trunk in the axis of rotation (L3, L4, and L5). To maintain this static work posture, an equal and opposite force must be provided by the paraspinal muscles of the lower back, in which the lever resistance is many times greater than the force of the lever. This indicates that the lumbar muscles must contract to maintain this posture continuously at a high level, increasing the chances of fatigue, pain, and reduction of blood supply to the region.[18]

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