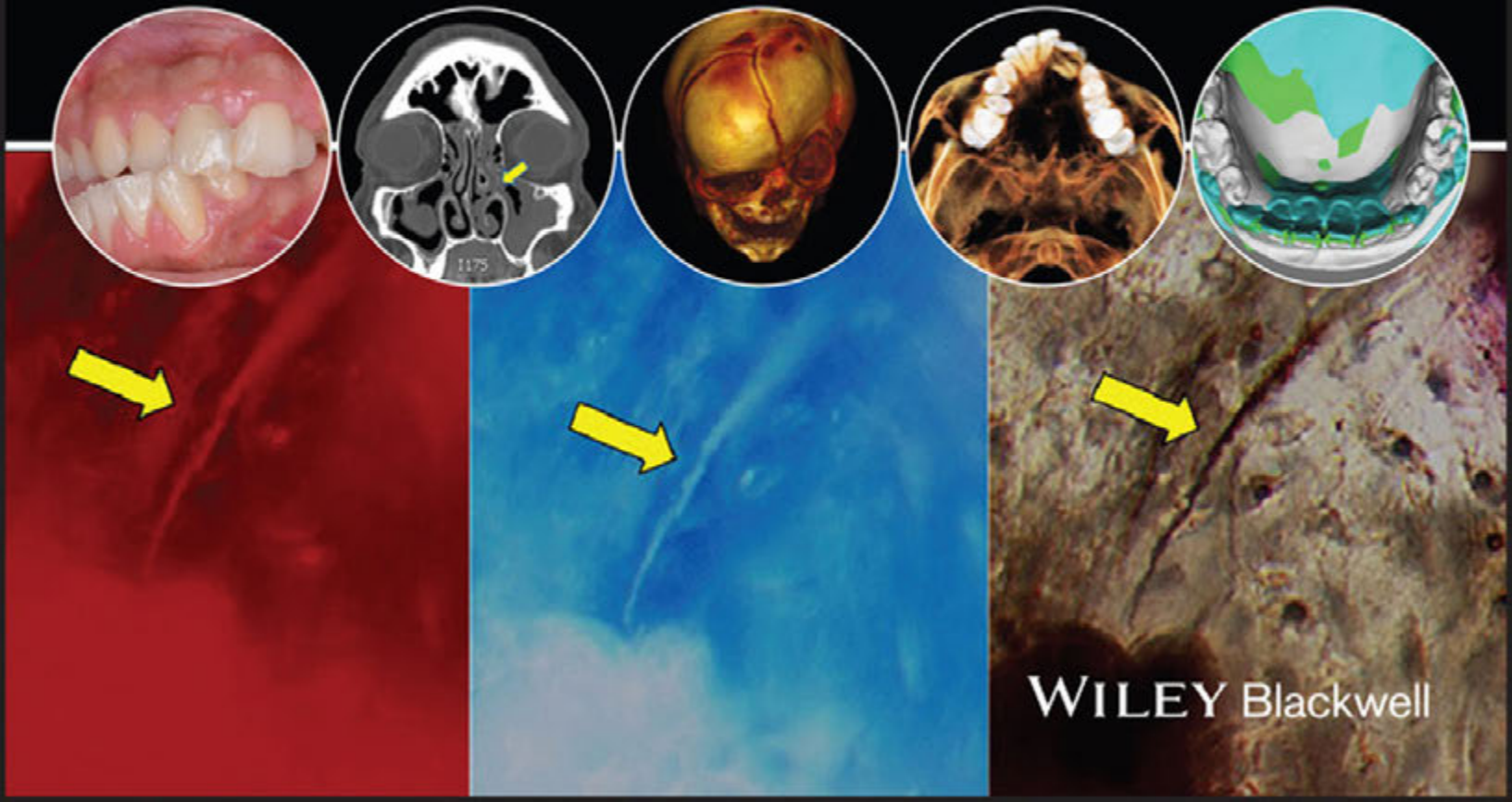
Second Edition

Integrated Clinical Orthodontics

Edited by

Vinod Krishnan • Anne Marie Kuijpers-Jagtman



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Preface to Second Edition

Orthodontics, from a technique-oriented profession, has evolved into a comprehensive specialty with a rapidly expanding scope, involving increased collaboration with experts from other disciplines. These interdisciplinary interactions provide the orthodontist with valuable information about individual patients, leading to modifications in diagnosis and treatment plans. Further, this approach has enabled orthodontists to carefully dissect, process and compare information across subject boundaries. Apart from the development of critical thinking, exposure to new ideas and frameworks evokes creativity leading to the development of innovative ideas.

Like many textbooks, the success of the first edition of 'Integrated Clinical Orthodontics' published in 2012, was accompanied by the realization that knowledge is subject to change. We understand that genuine wisdom stems from acknowledging that what we consider true today may appear absurd tomorrow. This second edition of 'Integrated Clinical Orthodontics' signifies a progression in this understanding. Our intention is for this book to serve as an extensive and current resource, offering comprehensive insights into orthodontic care within the context of related disciplines associated with our profession.

Just as in the first edition, we have chosen topics that clearly demonstrate the areas where orthodontists interact with experts from other fields, aiming to improve patient care. The new textbook provides a broad discussion of the basic and clinical sciences that are crucial to the understanding, diagnosis, and management of orthodontic patients. Nearly all existing chapters have been updated. To enhance its educational value, we have divided the book into five sections that reflect the areas where orthodontists, medical and dental specialists, biologists, geneticists, biomedical engineers, and other scientists intersect in modern orthodontics.

The inclusion of new chapters reflects the progress made in comprehensive orthodontics. This second edition features new chapters on endocrinological conditions, nutrition in orthodontics practice, neuromuscular diseases, orthodontics for children with disabilities, artificial intelligence in orthodontic practice, and the seven pillars of professionalism, among others.

We extend our heartfelt thanks to the authors from a diversity of disciplines for their outstanding contributions to this book, sharing their knowledge and passion to make orthodontics an even better discipline, thereby making a difference for the patients. We would also like to express our sincere appreciation to those, who critically analyzed the first edition of the book and pointed out its shortcomings so that we could anticipate them in the second edition. We express our gratitude to our publisher, John Wiley and Sons, especially Susan Engelken, Loan Nguyen, Katherine King, Fraser Dart, Oliver Raj, Keerthana Baskaran, Pavithra Chandrasekharan, Anitha Jasmine Stanley, and our copyeditor Sally Osborn, whose expertise greatly assisted us in preparing this second edition.

The benefits of an integrated approach to orthodontic care have long been recognized. In 2016 the FDI World Dental Federation developed a new definition of oral health, emphasizing its multifaceted nature. According to the new definition, oral health encompasses various aspects such as speaking, smiling, smelling, tasting, touching, chewing, swallowing, and expressing emotions through facial expressions, with confidence, free from pain, discomfort, and diseases of the craniofacial complex (head, face, and oral cavity). Modern orthodontics aligns perfectly with this concept. Simultaneously, our understanding of the importance of evidence-based practice has grown significantly. We fully acknowledge that there is still a lack of evidence in many areas covered in this textbook. However, even in the absence of evidence, we must still provide treatment to our patients! We hope that this book inspires orthodontists and postgraduates to look beyond their own field, ultimately benefiting the patients they treat.

Vinod Krishnan
Anne Marie Kuijpers-Jagtman
Editors

Preface to First Edition

The subject of this book, Integrated Clinical Orthodontics, seemed initially to be a straightforward topic. After all, we know that we depend on each other, in all walks of life, not excluding orthodontics. Therefore, we thought that it would be helpful to try to compose a publication that would reflect clearly each area where orthodontists interact with experts in other medical specialties, in an effort to upgrade their services to their patients.

Each individual who needs, seeks, or receives orthodontic care, differs from every other individual, molecularly, functionally, and esthetically. This natural variability is reflected in the orthodontic clinic, defining the identity of the specialty whose experts could be beneficial to the orthodontist and the patient alike. Our goal has been to learn from people engaged in clinical research in different medical fields, about their experience and advice on interactions with orthodontists. These interactions stem from the simple fact that none of us knows everything, and whether we like it or not, we depend on the professional opinions of our colleagues in other specialties, whose knowledge can remedy the voids in our own.

In planning the contents of this book, we immediately realized that there are many fields of knowledge that can augment the diagnostic and therapeutic capabilities of the orthodontist. In fact, we were amazed at the large number of these specialties, clearly reflected in the number of chapters in this book, 25, each dedicated to a specialty whose members interact with orthodontists. This increasingly widening scope of orthodontics is enabled by the availability and relative ease of electronic communication, and the expanding new findings in medicine and dentistry. It becomes increasingly difficult to command all relevant information about emerging new and exciting fields, such as tissue engineering and stem cells, and becoming aware of ongoing progress in seemingly traditional fields, such as genetics, psychology, and material science. Interaction with others seems to offer the means to clarify and confirm the identity of clinical findings in the diagnostic phase, and elucidate the road ahead, in terms of treatment plans and the choice of the most suitable mechanotherapy for the individual patient.

The concept emerging from this book is that orthodontics is not merely an exercise in wire bending, but rather a specialty leaning on many others. Interactions, whenever indicated, between the orthodontist and other medical specialists are a powerful tool on the way to excellence. In short, we would like to see each and every reader of this book to think like a healthcare professional and as a conscientious member of the dental profession who wishes to bring credit upon a high calling that has lifted itself from a questionable mechanical art to a most respected and esteemed health service to humankind.

We would like to extend our heartfelt thanks to all our contributing authors, who have generously shared their valuable knowledge and wisdom for the benefit of all those who are eager to learn about the advancements in ' science of orthodontics'. We were excited to read the manuscripts and are hopeful that the response of our esteemed readers will be the same too. Although the chapters are based on the contributors' own work and experiences, all the information can be applied to similar settings across the world.

We would also like to express our sincere gratitude to all the staff at Wiley - Blackwell, Oxford, UK, especially Sophia Joyce, Nick Morgan, Catriona Cooper, Lucy Nash, and James Benefield, as well as Lotika Singha (copyeditor), and Anne Bassett (project manager) whose relentless efforts helped us to accomplish this laborious, but fulfilling, task.

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The Increased Stature of Orthodontics

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Summary

Orthodontists treat patients with orofacial anomalies, including malocclusions, by applying mechanical forces to the crowns of teeth. These forces are transmitted to the tissues surrounding the roots of the teeth, enticing their cells to remodel these tissues, thereby enabling the teeth to move to new, preferred positions. Like any other tissues and organs in the human body, dental tissues and cells are controlled by the nervous, immune, vascular, and endocrine systems, as well as by factors such as psychological stress, nutrition, medications, and local and systemic diseases. Since the jaws are integral parts of the body, orthodontic diagnosis must include detailed information on any deviation from general health norms, and these data should be reflected in the treatment plan. Therefore, when specific pathologies are identified, an interaction with the appropriate healthcare provider who is treating the patient should occur, or a referral made to another specialist. The advice obtained from these experts can have a substantial impact on the orthodontic diagnosis and treatment plan. Continuing advances in medicine and dentistry increase the scope, importance, and value of these interactions. This introductory chapter discusses the need and rationale for interactions in specific situations, and this book includes details of conditions that require advice from specific specialists. The focus on this expanding scope is derived from the notion that biology plays a pivotal role in orthodontics, and that pertinent information regarding the health status of individual candidates for orthodontic treatment might have long-lasting effects on the course and outcomes of orthodontic treatment.

Facial esthetics, balance, and harmony, and/or their absence, have attracted attention from time immemorial, by artist and art viewer alike. Facial expressions can readily reflect various moods, emotions, and feelings, thereby conveying unspoken messages from person to person. The mouth is an essential component of this anatomical–physiological–emotional complex, by virtue of its ability to participate actively in these functions, involving its soft (cheeks, lips, and tongue) and hard (jaws and teeth) tissues. Painters, sculptors, and photographers have noted these features, and frequently, when creating images of human faces, included the rest of the body, or at least the torso, in their artwork, demonstrating acceptance of the principle that the face and the rest of the body are one unit. The specialty of orthodontics is taught predominantly as a field of endeavor dedicated to the improvement of orofacial esthetics and function. Consideration of biological principles and constraints is shadowed by the desire of both the patient and his/her orthodontist to achieve noticeable improvement in the position and location of the malpositioned crown(s), ignoring the fact that the crowns are anchored in the jaws by their roots, which are surrounded by tissues that act and react like any other organ to any local or systemic factor that comes their way. This situation is like an iceberg, visible partially above the water surface, but invisible under it.

Malocclusions are situations where individual teeth or entire dental arches are positioned in undesirable locations, either esthetically or functionally. The goal of orthodontics is to correct or minimize deviations from accepted normal

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characteristics of dental occlusion, orofacial function, and esthetics. We tend to focus on these deviations from normalcy as the main target of our specialty, while keeping other health-related issues far in the background, sometimes behind the horizon, as if a malocclusion exists in a vacuum, detached from the rest of the body. Maintenance of this outlook may, however, jeopardize the quality of orthodontic diagnosis, treatment plan, outcome, and long-term maintenance of the corrected malocclusion. What is required for attainment of optimal results in orthodontics is broadening of its scope, to include other specialties, dental and medical, that may expose etiological factors, and biological processes that could determine the nature of the cellular/tissue response to mechanotherapy. In short, we should not treat a malocclusion, but rather *a person* with a malocclusion (McCoy, 1941; Kiyak, 2008).

Presently, orthodontics is still viewed by the general population as a field occupied mainly by concerns about facial esthetics, and limited to the application of "braces" or aligners to crooked teeth. This image has been cultivated and nurtured by many members of the orthodontic specialty, because it simplifies their lives by highlighting the known fact that teeth move when subjected to mechanical forces. This outlook is deeply embedded in the curricula of the majority of the orthodontic educational/training programs around the world. Orthodontic residents are made to believe, at least subconsciously, that correcting a malocclusion in a human being is just as easy as moving metallic teeth through the warm, soft wax of a typodont (Davidovitch and Krishnan, 2009). Furthermore, this attitude has encouraged general dentists to engage in the practice of orthodontics without obtaining proper education that would qualify them for this task. An example of a poor outcome of such treatment is seen in Figures 1.1 and 1.2. However, orthodontics, which had been viewed until recently as being mainly a technique-oriented profession, has evolved into a comprehensive specialty, with a rapidly expanding scope, increasingly interacting with experts, among others, in biology, medicine, dentistry, engineering, and computer science. These interactions can provide the orthodontist with important information pertaining to individual patients that may lead to modifications in the diagnosis and treatment plans.

Voluminous expansion of the scientific and clinical bases of orthodontics is occurring in various directions, biological and technical. The role of biology in the diagnosis, treatment planning, and treatment of individual patients is becoming increasingly clear (Cartwright, 1941; Davidovitch and Krishnan, 2009). An orthodontist may be an expert in mechanics, but he/she is not a nutritionist, psychologist, pediatrician, endocrinologist, primary care physician, oral and maxillofacial surgeon, endodontist, prosthodontist, or any other medical and/or dental specialist. Therefore, it seems only prudent to request advice from other specialists whenever a condition is recognized in a person seeking orthodontic treatment, or in a patient who is already being treated.

The reality is that people who possess malocclusions may also have pathological conditions that could have significant impacts on the course and outcome of orthodontic treatment. This probability creates a need to consult and interact with other specialists familiar with an individual patient, or with the health problem afflicting this individual. Moreover, some people may have communicable diseases that may endanger the well-being of others who are in their environment. The existence of rapid communication systems enables an orthodontist to easily seek advice from other specialists, leading to the crafting of diagnoses and treatment plans tailored specifically for each individual patient. These systems are also very useful in fostering strong doctor–patient trust, increasing cooperation and improving outcomes.

Likewise, recent advances in material science, metallurgy, and biomedical engineering have introduced an increasing array of alloys, capable of generating a wide spectrum of mechanical forces. A continuous interaction between the orthodontist and these engineers has already produced major changes in the design of orthodontic brackets, and the composition of the metallic and nonmetallic wires that generate the proper orthodontic forces, while controlling factors such as friction and strain. This interaction is fertile ground for the development of new appliances capable of engendering optimal tooth movement, biologically and mechanically, for each patient. The era has come wherein orthodontists are able to print customized brackets and wires tailored for the individual patient and can track individual patient progress with dental monitoring devices. Orthodontics nowadays is largely incorporating reverse engineering in the treatment planning and execution process, wherein malocclusion is treated to its end point with the help of digital models and computerized software and staged sequentially to fabricate aligners.

The pioneers of modern orthodontics were pathfinders in a field full of challenges and obstacles. Those leaders utilized the best therapeutic tools available for eliminating malocclusions, paving the way for greater achievements by their successors. Edward H. Angle, the "father of modern orthodontics," advocated at the end of the nineteenth century the inclusion of basic medical sciences, such as anatomy, physiology, and pathology, in the curriculum designed for educating dentists as specialists in orthodontics. He apparently clearly saw the functional connection between the head and the rest of the body. Three decades on, one of his students, Albert Ketcham (1929), in attempting to elucidate the reasons for dental root resorption (a major undesirable side effect of tooth movement), concluded that the etiology is associated with the patient's metabolism. In the following years, resorption of roots was attributed to factors such as nutritional deficiencies, hormonal

Figure 1.1 Poorly executed orthodontic treatment by a general practitioner. Ignoring the absence of mandibular central incisors, the practitioner extracted all the second premolars but was then unable to close the spaces entirely, ending with excessive overjet and a very deep bite.

fluctuations, genetic predisposition, and psychological stress. All these factors point to the fact that tissue remodeling that facilitates tooth movement is dependent, at least in part, on the unique pathophysiological profile of the individual patient. Detailed information on this biological profile may be obtained from several different healthcare providers familiar with individual patients.

However, despite recognition of the importance of life sciences in orthodontic education and practice, considerable emphasis is still being placed on the mechanical aspect of

Figure 1.2 Another patient with poorly executed orthodontic treatment by a general practitioner. Poor planning is evidenced by extraction of all premolars (first and second) from all quadrants and finishing with lack of space closure, deep bite, rotated maxillary and mandibular molars, and posterior crossbite on the right side of the dental arch.

this specialty. Consequently, conditions such as excessive root resorption are labeled idiopathic, unpredictable, and an "act of God." These explanations fly in the face of the long-recognized principle of the intimate union between biology and mechanics in orthodontic therapy. This proximity was first suggested by Farrar (1888: 658), who speculated that tooth movement is facilitated by either resorption or bending of the alveolar bone, or by both processes. Farrar's comment was surprisingly correct, although it was based on empirical evidence. Experimental evidence supporting Farrar's hypothesis was provided by Sandstedt (1904) and by Baumrind (1969). While Sandstedt used histological sections to demonstrate that paradental cells are responsible for the force-induced tissue remodeling, Baumrind confirmed in experiments on rats that orthodontic forces do indeed bend the alveolar bone.

The broadening scope of orthodontics

In 2016 the FDI World Dental Federation developed a new definition of oral health that clearly states: "Oral health is multi-faceted and includes the ability to speak,

smile, smell, taste, touch, chew, swallow and convey a range of emotions through facial expressions with confidence and without pain, discomfort and disease of the craniofacial complex (head, face, and oral cavity)" (Glick et al., 2017). Orthodontics fits perfectly within this concept. Based on this definition, the Royal Dutch Dental Association defined orthodontic care as follows: "Orthodontic care is an integral part of oral health care and is concerned with optimizing the position of the teeth and the growth of the jaws and surrounding structures and makes an essential contribution to the health of an individual by promoting their psychosocial well-being and by creating optimal conditions for other facets of oral health and oral health care" (KNMT, 2020).

Nowadays orthodontics needs this kind of more holistic approach. Ideally, orthodontics should be practiced in a facility that houses all other medical specialists, such as a hospital or a large group practice. In such an environment, reaching various experts and obtaining their advice about health-related problems of individual orthodontic patients may be accomplished with relative ease. Specialists such as primary care/family physicians, orthopedists, surgeons, psychologists, and nutritionists may be within walking distance from the orthodontic clinic. However, the widespread network of electronic communications today has enabled an orthodontist to refer a patient for consultation and receive the specialist's opinion in a timely fashion, without dependence on geographical proximity or venue location.

Contemporary orthodontics is a fusion of biology and mechanics, starting with the process of diagnosis, which is based on estimating and documenting the extent of malocclusion, as well as asking: "Who is the patient, biologically?" This question must be answered before any plans for tooth movement can be contemplated. The presence of any systemic or local pathological condition may cause significant alterations in the orthodontic therapeutic plans for any and every individual patient, regardless of age or gender. A comprehensive orthodontic diagnosis should start with a detailed presentation of the patient's biological profile, including all conditions that may have an impact on mechanotherapy. This segment of the diagnosis is followed by a detailed description of the malocclusion. The biological segment is the part where interaction with specialists in various medical fields is expressed and is later reflected in the crafting of an individual treatment plan. A brief example of such a diagnosis is as follows: "AZ is a 34-year-old female nurse, mother of two children, with multiple sclerosis that started 5 years ago, with a history of familial neuropathies. She has a Class II Division 1 malocclusion, with a steep mandibular plane, an 8° ANB angle, and a 12 mm overjet." This diagnosis is a presentation of the main systemic and orofacial findings, which together pave the way for a proper treatment plan. For the sake of providing the best treatment plan for AZ, it would be beneficial to seek the advice of the other specialists who take care of her, such as her personal physician, neurologist, and nutritionist. Their opinions may turn out to be valuable in guiding the orthodontist toward a treatment plan that would be optimal and practical for this individual patient.

A similar malocclusion in a different patient may read as follows: "RM is a 14-year-old boy, entering the pubertal growth spurt, who has type 1 diabetes, allergies, and asthma, with a Class II Division 1 malocclusion, a steep mandibular plane, and an 8 mm overjet." This concise but detailed diagnosis implies that the patient is growing and has health-related issues that may overshadow the orthodontic problem and its treatment outcome. Systemic issues of this nature, involving the immune, endocrine, and vascular systems, may alter the response of cells surrounding the teeth to applied mechanical stress, modify the velocity of tooth movement, and contribute to the creation of undesirable side effects to orthodontic treatment, such as irreversible loss of alveolar bone and shortening of dental roots. Moreover, if medical and/or socioeconomic problems are ignored, and are allowed to persist, maintenance of the corrected malocclusion may be jeopardized. Therefore, in the case of RM, it may be advisable for the orthodontist to communicate with the patient's pediatrician, endocrinologist, and nutritionist prior to solidifying the diagnosis and treatment plan.

The orthodontic patient as a human being

Orthodontists do not only see young individuals, who are ready to face the world with a lot of enthusiasm and confidence, but also adult patients with various needs and expectations. In some instances patients may be having psychosocial issues, and may seek orthodontic therapy in an attempt to alleviate their personality deficits, improve their social status, or find solutions to problems in their professional and personal life. It is extremely important to realize that every patient considered for treatment is an individual with a metabolic profile and physiological traits unique to him/her (Bartley et al., 1997), even though all humans share similar genetic, anatomical, physiological, and biochemical bases. The interindividual differences may arise from physical, social, ethnic, psychological, and metabolic variations, among other factors. It is important to realize that orthodontic treatment is provided to vital tissues that respond in a similar fashion in all patients. However, the extent, duration, and outcome of this response are frequently dependent on biological factors only remotely related to the malocclusion at hand.

The pattern and timing of craniofacial growth and development events are intimately associated with somatic growth-related functions, controlled and regulated by myriad chemical and physical factors, of internal and external origin, interacting with target cells in many or all organs and systems. This complex reality faces every orthodontist, as well as any other healthcare provider. It is rather

unrealistic to expect that any one individual, in any medical specialty, would be able to comprehend, manage, and memorize all this voluminous knowledge. Hence there is a need for the orthodontist to keep abreast of new developments in the entire field of medicine, and to interact with members of other specialties whenever a situation arises that requires input from other experts.

One fundamental interaction in this formula is between orthodontists, who move teeth with mechanical forces, and the experts who create the means to generate these forces: biomedical and metallurgical engineers. The requirement for perpetual interaction between experts in these entities is because orthodontic tooth movement requires close interaction between the biological and the mechanical environments (Krishnan and Davidovitch, 2006a; Meikle, 2006) and, even in a healthy patient, the response to orthodontic forces can vary from time to time, because the duration of treatment is often measured in years. In addition, the presence of an underlying ailment that affects the physiological condition may alter the nature of the acute and chronic inflammation that is a core event in tooth movement, and modify craniofacial growth and development (Alvear et al., 1986). Cellular signaling molecules generated either in the vicinity of the periodontal ligament or in distant sites have the potential to disrupt tooth movement by altering the levels of biomolecules in the local biological environment of the periodontal ligament (Krishnan and Davidovitch, 2006b).

The patient's biological status: does it influence orthodontic treatment?

Due to the uniqueness of every individual patient's biology, it is imperative for the orthodontist to create and maintain open communication channels with practitioners in every medical field. Patients may be referred for consultation to their personal physician, or to experts in specific areas, such as endocrinology, neurology, immunology, genetics, metabolism, pulmonology, nutrition, psychology, and infectious diseases. Each organ or tissue system in a pathological state may have profound effects on paradental cells and tissues, by transferring signal molecules through the vascular system to any tooth being moved, and all the cells surrounding it.

Inflammation and cellular mechanotransduction are central coordinators of orthodontic tooth movement, which ushers leukocytes and plasma out of the mechanically stressed capillaries, which become hyperpermeable in reaction to the release of vasoactive neurotransmitters from the strained nerve terminals. In this fashion, leukocytes that had become primed in remote diseased organs can enter strained dental and paradental tissues, and interact with cells carrying receptors for signaling molecules synthesized by the migratory immune cells. Experiments with human periodontal ligament (PDL) fibroblasts in vitro revealed that these cells respond readily to cytokines, growth factors, colony-stimulating factors, and chemo-attractant signals, all of which are produced and released by the newly arrived leukocytes (Saito et al., 1990a, b). Recent research has revealed the difference in morphology as well as reaction of PDL cells from young and adult patients subjected to the application of orthodontic force (Figure 1.3). Adult PDL cells exhibited senescent changes through increased beta-galactosidase activity that, along with an increase in the inflammatory response and bone resorption activities, was evident by increased prostaglandin E2 (PGE2), interleukin (IL)-1B, and acid phosphatase mRNA expression levels (George et al., 2020; Mohanakumar et al., 2021). This intimate correlation between tooth movement and pathological conditions that happen elsewhere in the body is the main reason for interacting with physicians, nutritionists, psychologists, or other experts in healthcare provision.

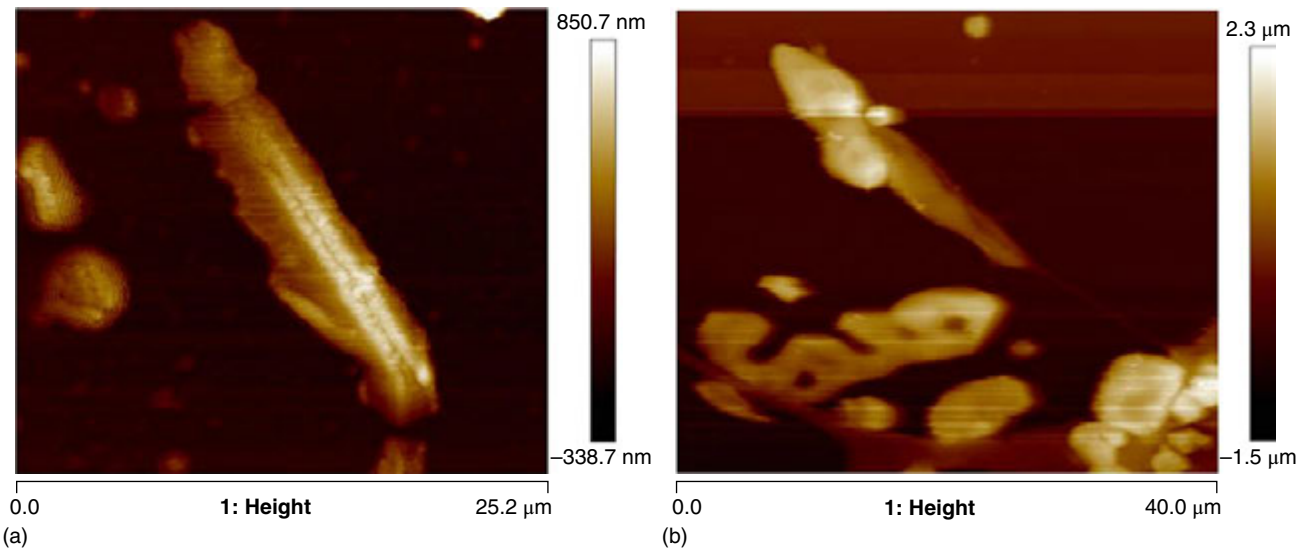


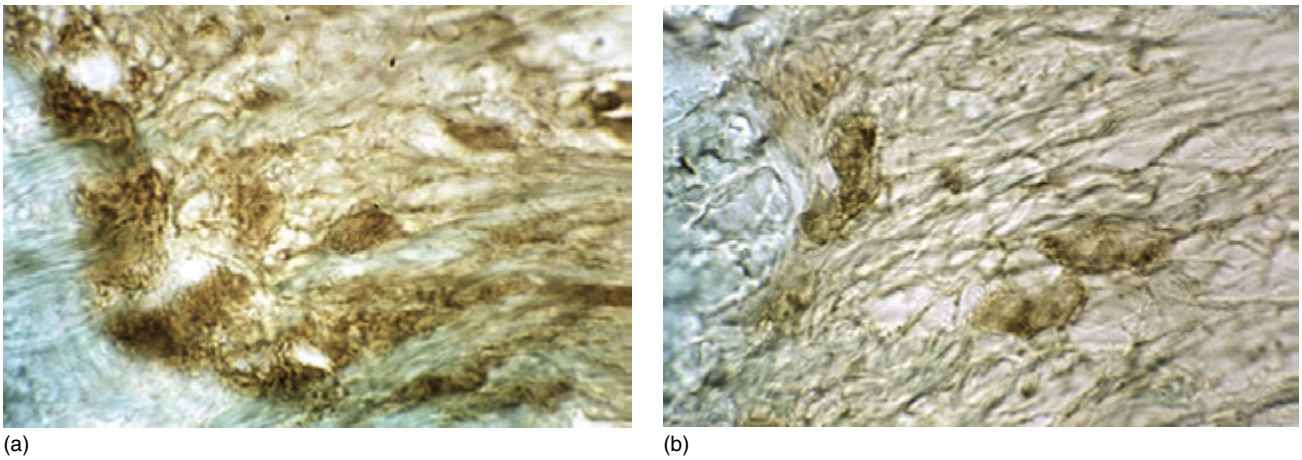
Figure 1.3 Representative atomic force microscopy images after nanoindentation showing an increase in surface irregularities and protrusions in the cell surface of periodontal ligament fibroblasts. (a) Young fibroblast and (b) adult fibroblast cells.

Many individuals seeking orthodontic care have systemic ailments, such as asthma, and are usually already under treatment for these conditions at the time of their orthodontic diagnosis appointment(s). This treatment often entails the use of various prescription and/or over-the-counter medications. Some of these medications may have insignificant effects on the process of tissue remodeling evoked by the orthodontic forces, but others, such as steroidal and nonsteroidal anti-inflammatory drugs, anti-cancer medications, immune suppressors, statins, and anti-osteoporotic medications, may reach the cells in and around moving teeth by exiting, in the plasma, through capillaries that have become hyperpermeable by the applied stress (Krishnan and Davidovitch, 2006b). It is therefore important to record all the medications taken regularly by a patient before the onset of orthodontic treatment, as well as during the course of therapy. Once a complete list of medications taken regularly by a patient is obtained, it is essential to search for information about their desirable and undesirable effects. This information can be readily found on the internet and in current pharmacopeias. An example of a profound effect of a nonsteroidal anti-inflammatory drug on cells involved in orthodontic tissue remodeling is demonstrated in Figure 1.4, showing the mesially located, stretched PDL and alveolar bone surface lining cells of a maxillary cat canine that had been moved distally for 24 h, with a force of 80 g. The tissue sections were stained immunohistochemically for PGE2, a ubiquitous inflammatory mediator. A section taken from a control cat untreated by the nonsteroidal anti-inflammatory drug indomethacin shows cells intensely stained for PGE2, while a section obtained from an indomethacin-treated cat demonstrates a marked reduction of staining intensity, suggesting that this drug may have a profound effect on tooth movement.

Nutrition may play an important role in determining the pattern and course of tooth movement (Hickory and Nanda, 1981; Palmer, 2007). A modern diet consists of proper amounts of proteins, carbohydrates, lipids, vitamins, and trace elements. However, within the same community, marked differences between individuals may be found in the relative proportion of each dietary component, and even greater differences are known to exist between members of diverse communities, despite their geographical proximity. Some items in the diet may be essential for eliciting a vigorous cellular response to mechanical forces. For example, vitamin C is an essential co-factor in the synthesis of collagen by fibroblasts, and vitamin D_3 is a key regulator of the mobilization of calcium into and out of the intestine, kidney, and skeleton. Proteins provide the amino acids needed for building and remodeling tissues surrounding moving teeth; carbohydrates supply the energy required for all cellular activities; and lipids are a critical part of every cell's plasma membrane.

Some dietary components may be detrimental to the patient's health and well-being and have a negative effect on dental and paradental tissues. In the case of alcohol, its chronic excessive consumption may cause dental root resorption in orthodontic patients by causing liver cirrhosis, disrupting the hydroxylation of vitamin D_3 in the liver, thereby evoking increased production of parathyroid hormone (PTH), necessary for the maintenance of calcium homeostasis (Ghafari, 1997). This hormone is implicated in the resorption of mineralized tissues, including dental roots. For these reasons it may be helpful to obtain detailed information about the dietary habits of every patient prior to the onset of orthodontic treatment. An evaluation of individual daily diets by a qualified nutritionist may supply the orthodontist with important clues regarding expectations of individual tissue responses to orthodontic mechanotherapy.

Regulation of mammalian body functions is dominated to a large extent by three systems: the nervous, immune, and



(a) (b)

Figure 1.4 Immunohistochemical staining for prostaglandin E2 (PGE2) in sagittal sections, 5 μm thick, of maxillary canines of 1-year-old cats, after 24 hours of distal movement by an 80 g translatory force. (a) Periodontal ligament (PDL) tension site of control cat, showing distinct staining in alveolar bone osteoblasts. (b) PDL tension site of a cat injected subcutaneously with indomethacin, 5 mg/kg, at the time of appliance activation. The staining intensity for PGE2 in osteoblasts and PDL cells is light.

endocrine systems. Persons seeking orthodontic care sometimes have ailments that affect one or more of these systems. Treating such patients orthodontically with little consideration for their systemic abnormalities may result in some unpleasant surprises for patients, as well as for their orthodontists. For example, a patient with an existing condition such as multiple sclerosis may develop trigeminal neuralgia early in the course of orthodontic treatment, because of the acute pain generated every time the orthodontic appliance is activated. The pain may even be amplified because of the direct contact between the denuded, unmyelinated trigeminal nerve fibers. In cases such as this, and in patients with other neurological diseases, either central or peripheral, administration of orthodontic forces may exacerbate the neurological condition and/or be affected by it. Moreover, medications taken by these patients may also alter the pattern of tissue response to orthodontic forces (Krishnan and Davidovitch, 2006b). Therefore, it may be prudent to seek the advice of the neurologists treating such patients.

The immune system is a network of biological structures and processes within an organism that protects against disease by identifying and killing pathogens and tumor cells. It detects a wide variety of agents, from viruses to parasitic worms, and needs to distinguish them from the organism's own healthy cells and tissues in order to function properly. Detection is complicated as pathogens can evolve rapidly, producing adaptations that avoid the immune system and allow the pathogens to successfully infect their hosts (Abergerth and Gudmundsson, 2006). The immune system provides the leukocytes required for the induction and maintenance of inflammation, which is the mechanism whereby tissue remodeling facilitates tooth movement. Disorders of the immune system, such as immunodeficiency that occurs when the immune system is less active than normal, result in recurring and life-threatening infections. Immunodeficiency can be either the result of a genetic disease, such as severe combined immunodeficiency, or secondary to pharmaceutical therapy or an infection, such as acquired immune deficiency syndrome (AIDS), which is caused by the retrovirus human immunodeficiency virus (HIV). In contrast, autoimmune diseases result from a hyperactive immune system attacking normal tissues, as if they were foreign organisms. Common autoimmune diseases include Hashimoto thyroiditis, rheumatoid arthritis, diabetes mellitus type 1, and lupus erythematosus. Figure 1.5 shows intraoral views in a 39-year-old man with

Figure 1.5 A malocclusion in a 39-year-old man with several systemic diseases. (a) Frontal view of the dentition, demonstrating a midline shift and bilateral posterior crossbite. (b, c) Left and right views of the dentition, showing spaces resulting from prior tooth extractions. Tipping of teeth into the extraction sites is visible in both dental arches. (d) The maxillary periapical radiograph reveals severe shortening of the premolar and molar roots.

a history of diabetes mellitus type 1, Hashimoto thyroiditis, and depression. He had an obvious malocclusion, and his systemic diseases were being treated by a variety of medications. In view of the multiplicity of diseases and the numerous medications taken by this patient, the patient's physician's recommendation was to refrain from orthodontic treatment. The decision not to consider orthodontics was reached based on input from the patient's physician, dentist, and a prosthodontist.

The endocrine system is a system of glands, each of which secretes a specific type of hormone to regulate the body and act as an information signal system, much like the nervous system. A hormone is a chemical transmitter released from specialized cells into the bloodstream, which transports it to specialized organ-receptor cells that respond to it. Hormones regulate many functions of an organism, including mood, growth and development, tissue function, and metabolism. Together with the nervous system, the endocrine system regulates and integrates the body's metabolic activities. The endocrine system meets the nervous system at the hypothalamus. The hypothalamus, the main integrative center for the endocrine and autonomic nervous systems, controls the function of endocrine organs by neural and hormonal pathways.

Application of orthodontic forces increases the blood flow into the tooth and the paradental tissues (Kvinnsland et al., 1989; Ikawa et al., 2001) and their capillaries become hyperpermeable, fostering plasma extravasation. This local alteration in the vascular system can cause an increase in the tissue concentration of hormones, of which some, like parathyroid hormone, calcitonin, and thyroxin, are known to regulate bone metabolism (Copp and Cheney, 1962; Mundy et al., 1976; Parfitt, 2003; Martin, 2004; Poole and Reeve, 2005). Figure 1.6 presents photomicrographs of the alveolar bone and PDL, as seen in sections stained immunohistochemically for 3′,5′-adenosine monophosphate (cyclic AMP or cAMP). The sections were obtained from three young adult cats. Figure 1.6a is from an untreated (control) cat and shows mild cellular staining intensity for cAMP near a maxillary canine. Figure 1.6b is from a cat whose maxillary canine was subjected to 24 hours of distal movement. This figure is from the zone of tension in the PDL, demonstrating intense staining for cAMP, resulting from the orthodontic force. Figure 1.6c was derived from a cat that had been treated in the same manner as the one shown in Figure 1.4b, and in addition received a subcutaneous injection of PTH, 30 IU/kg, 2 h before euthanasia. In Figure 1.6c the cells are stained extremely dark, reflecting a high concentration of cellular cAMP. Since this cyclic nucleotide represents cellular activation by extracellular signals, it is reasonable to conclude that the biological response to orthodontic forces may be sensitive to hormonal concentrations in the blood. These concentrations are modified significantly by pathological conditions that develop in specific endocrine glands, suggesting that an opinion of an endocrinologist about the patient's hormonal profile could be very helpful in crafting a proper orthodontic diagnosis and treatment plan.

Orthodontists treat human beings, who sometimes are unable or unwilling to acknowledge and comply with their share of responsibility and effort dictated by the treatment regimen. Frequently, such behavioral patterns stem from psychological stresses, rooted in genetic, developmental, and/or environmental etiological factors. Hence, psychology is apparently a crucial element in determining and forecasting the degree of success or failure of orthodontic treatment. Psychology is a field that focuses on studying the mind. Psychologists attempt to understand the role of mental functions in individual and social behavior, while also exploring underlying physiological and neurological processes. Psychologists study such topics as perception, cognition, attention, emotion, motivation, brain functioning (neuropsychology), personality, behavior, and interpersonal relationships. Deviation from the norm in any of these areas may harbor the seed of failure of orthodontic treatment. A review of records of about 1100 patients who had completed orthodontic treatment revealed that those who had been diagnosed before the onset of treatment as having had psychological problems, such as mood swings and anxiety, displayed a high risk of developing excessive root resorption during the course of treatment (Davidovitch et al., 2000). This undesirable outcome could have been the result of alterations in the hypothalamic–pituitary–adrenal axis, caused by the psychological problems. Another unexpected side effect of orthodontic treatment in a psychologically stressed patient is alopecia totalis (Davidovitch and Krishnan, 2008) (Figure 1.7). Apparently, the mind is an important determinant of the degree of success of orthodontic treatment. Therefore, it seems advantageous to interact with a psychologist whenever a psychological issue is diagnosed, both before and during treatment.

Interactions between dentists who practice one or more specialties are almost axiomatic. Patients with malocclusions are frequently being referred to an orthodontist for an initial examination and assessment of the degree of need for orthodontic care. The referring person may be a general dentist who controls the dental health of the patient and his/her family, a periodontist, a pedodontist, or another dental specialist. After examining the patient, the orthodontist informs the referring dentist about his/her findings and recommendation, and whenever necessary they coordinate the timing of various treatment phases. However, sometimes elimination of a complex malocclusion, which involves the teeth, their surrounding tissues, as well as the facial muscles and skeleton, requires the construction of a comprehensive treatment plan by a number of specialists. Such is the case in caring for patients with orofacial clefts and other craniofacial anomalies, where teams of experts convene to discuss each patient's individual needs in a detailed and carefully coordinated

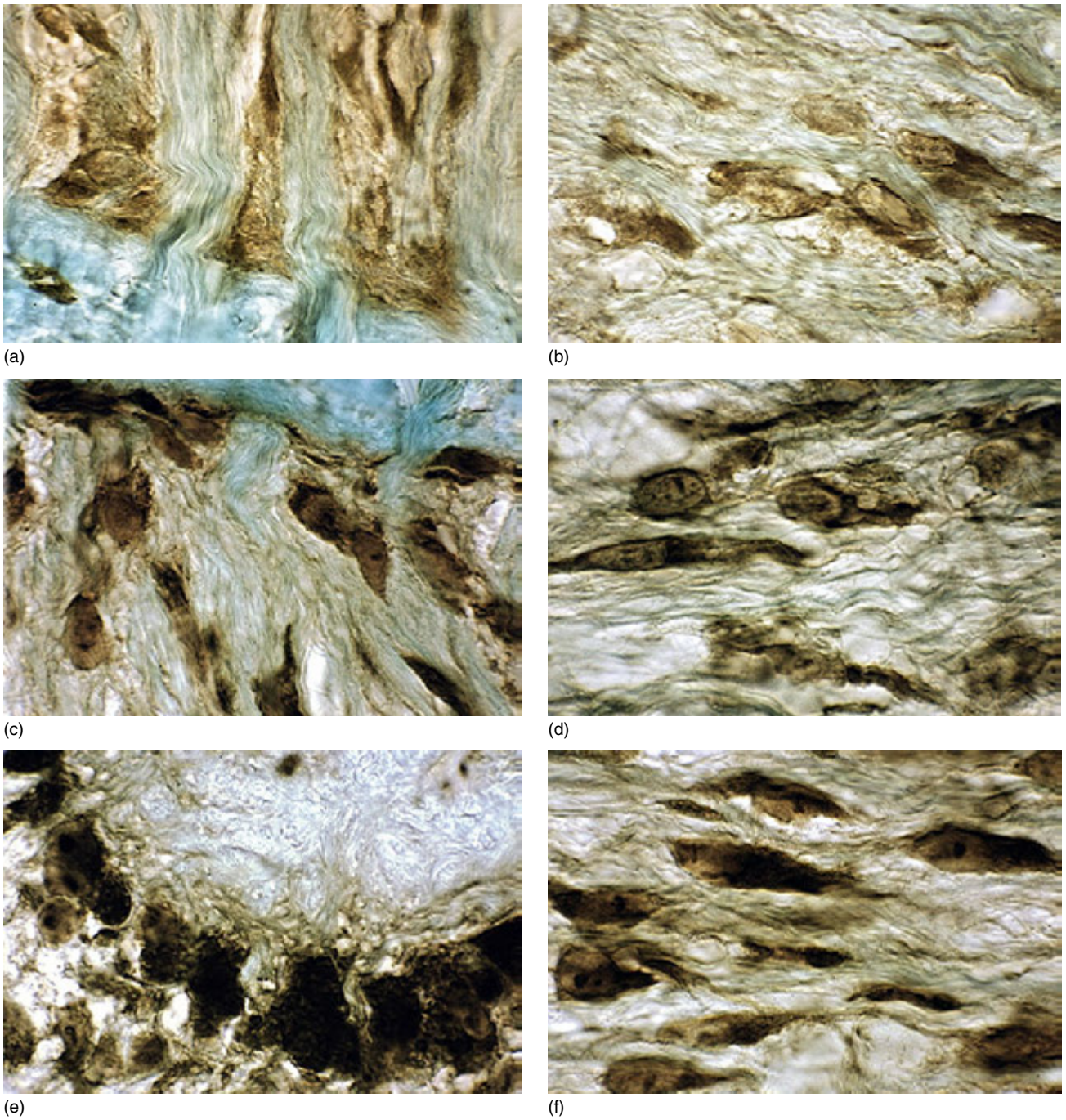
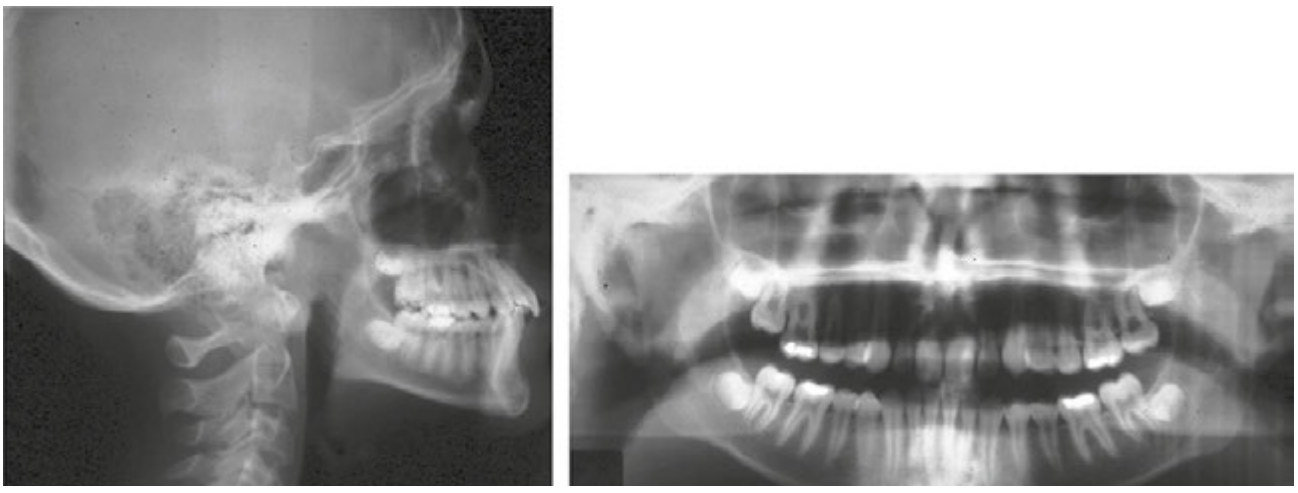


Figure 1.6 Immunohistochemical staining for cyclic adenosine monophosphate (cAMP) in sagittal sections, 5 μm thick, of maxillary canines of 1-year-old cats after 24 hours of distal movement by an 80 g translatory force. (a) Osteoblasts and (b) periodontal ligament (PDL) fibroblasts from a control cat (no orthodontic force). (c) Osteoblasts and (d) fibroblasts in the PDL tension site (the cat received orthodontic force, but no parathyroid hormone [PTH]). (e) Osteoblasts and (f) fibroblasts in the PDL tension site. This cat received orthodontic force and a subcutaneous injection of PTH, 30 IU/kg, at the time of the appliance activation. The intensity of staining for cAMP is light in the untreated control animal, pronounced in the animal that was treated by force alone, and very intense in the animal treated by force and PTH.

sequence. These teams include experts in pediatrics, plastic surgery, psychology, social work, nutrition, dentistry, and orthodontics. A similar team approach is adopted for the treatment of adults who require reconstructive treatment. The team in this case may include a general dentist and specialists in periodontics, endodontics, maxillofacial surgery, prosthodontics, and orthodontics.

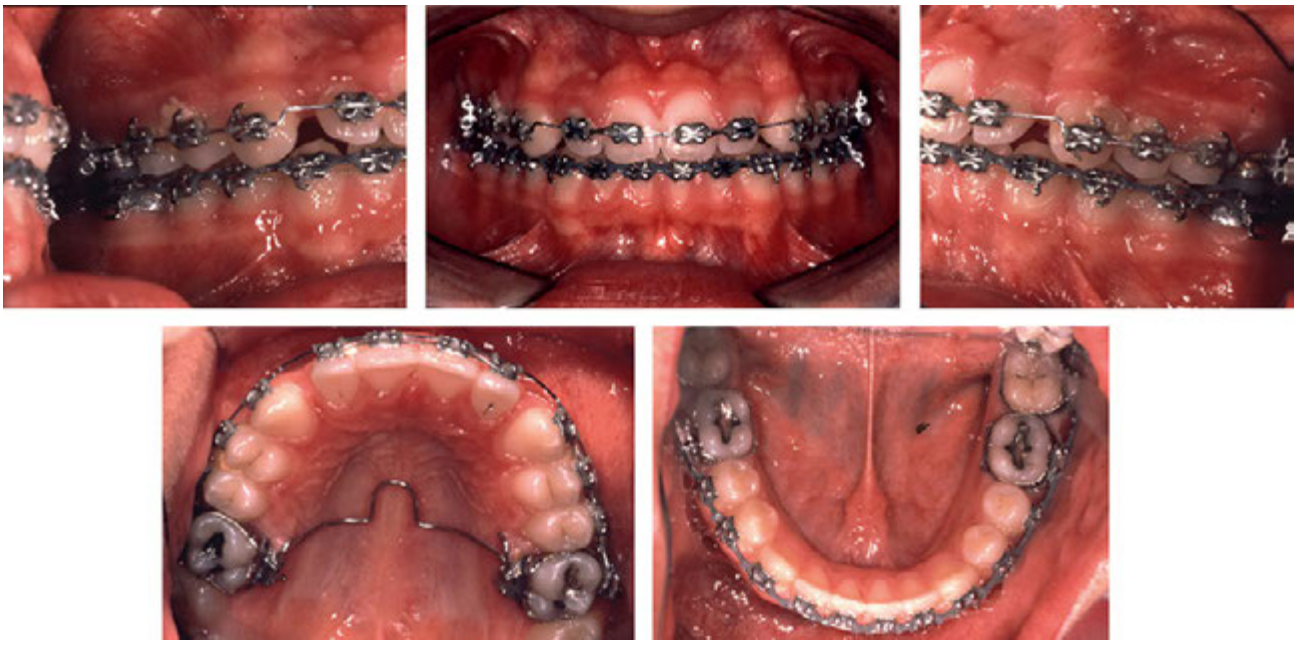
The orthodontist's professional wish-list includes a comfortable, painless experience for all patients, efficient treatment of short duration, avoidance of iatrogenic

(a)

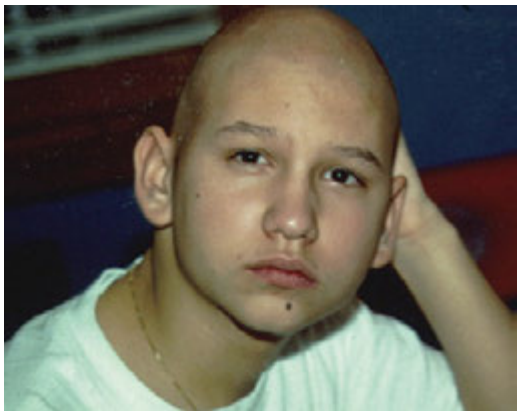


(b)

Figure 1.7 (a) Pretreatment extra- and intraoral photographs of MV, at age 12 years and 10 months. Note good symmetry; smiling picture revealing maxillary midline is shifted 3.5 mm, a convex profile. Teeth in occlusion show a deep anterior overbite (80–90%) and spaces between the maxillary incisors. The maxillary midline is shifted 3.5 mm to the right. On the right side, the buccal occlusion is neutral and spaces are seen between the maxillary incisors and mesial to the canine. Left side shows Class II Division 1 molar relationship as well as spaces between the maxillary incisors and mesial to the canine. Occlusal view of maxillary dental arch shows a parabolic shape, spaces between the anterior teeth from canine to canine, and distolabial rotations of both central incisors. Mandibular dental arch shows a U-shape, without any spacing or crowding of teeth. (b) Pretreatment lateral cephalogram demonstrating normal anteroposterior and vertical relationships between the jaws, a favorable inclination of the anterior cranial base and the palatal and mandibular planes, and a deep overbite in the incisor region. The panoramic radiograph reveals all teeth to be present and normal dental development.

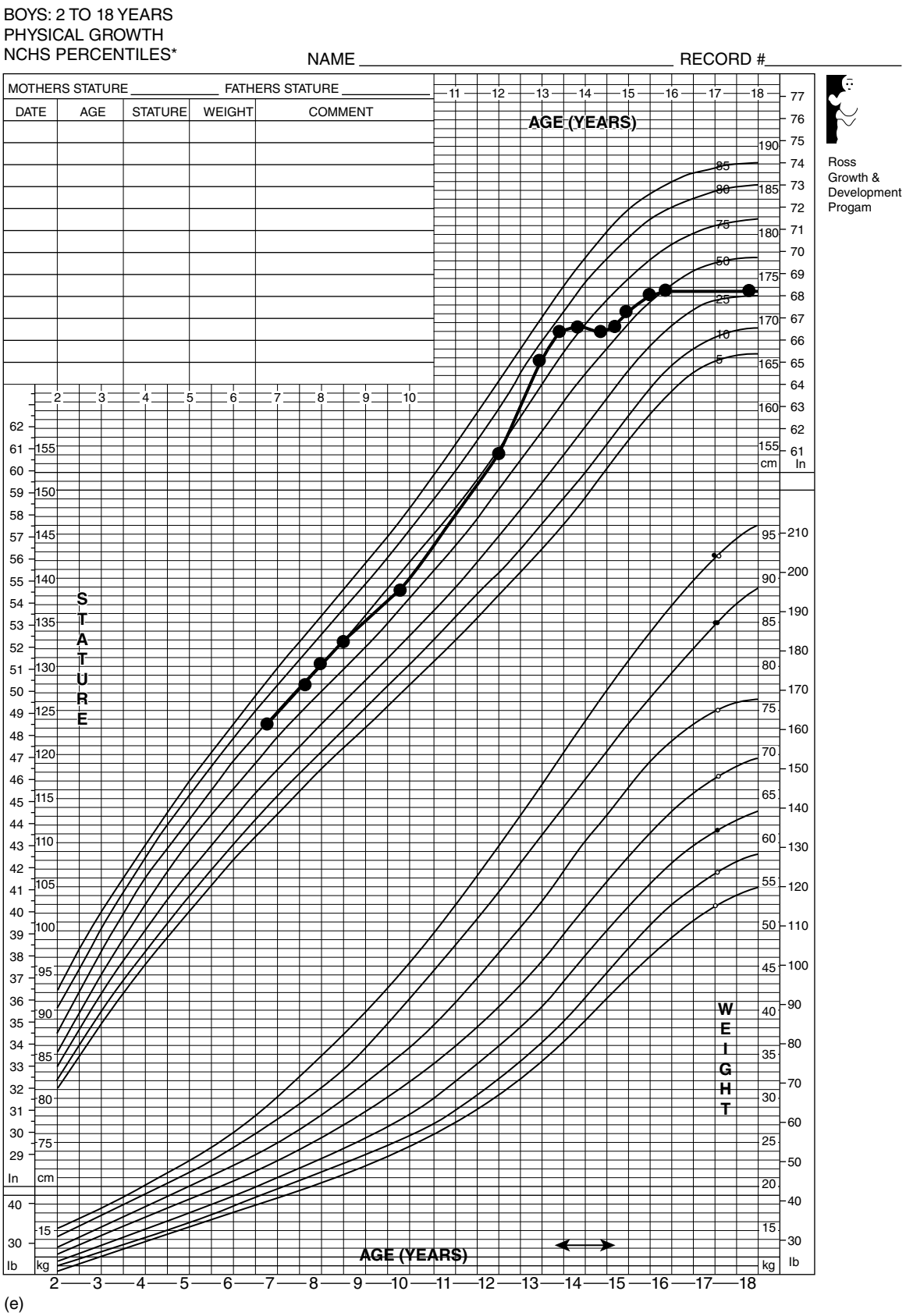


(c)



(d)

Figure 1.7 (*Continued*) (c) MV's dentition 1 year after the onset of orthodontic treatment. Frontal view and both left and right lateral views demonstrate accumulation of dental plaque and food debris in the canine and premolar regions between the brackets and the gingival margin. Occlusal view shows spaces between the maxillary canines and lateral incisors. (d) Photograph of MV 9 months after the beginning of orthodontic treatment, 1 month after he lost all his scalp hair (alopecia totalis). Source: Davidovitch and Krishnan (2008), courtesy of Quintessence Publishing Co. Inc., Chicago.



(e)

Figure 1.7 (*Continued*) (e) Physical growth (stature) curve of MV, revealing the somatic growth-inhibitory effects of the corticosteroid treatment that was implemented in an attempt to restart new hair growth. The hormonal treatment failed to stimulate hair growth.

(f)

(g)

Figure 1.7 (*Continued*) (f) Photographs of MV 11 months after the completion of his orthodontic treatment and 1.5 years of treatment with vitamin D_3. Apparently, this treatment mode was successful in restoring hair growth. (g) Extraoral photograph of MV taken in August 1999. His hair remained intact. Source: Davidovitch and Krishnan (2008), courtesy of Quintessence Publishing Co. Inc., Chicago.

damage, and a guarantee that the teeth have been moved to their best position, from where there is no relapse. The duration of tooth movement may be shortened significantly by decortication of the alveolar bone, leading to release of stem cells from the bone marrow, and the engineering of new tissues (Wilcko et al., 2009).

Conclusions

Treatment of a malocclusion requires high technical skills and a thorough comprehension of biological sciences, because teeth transfer the applied orthodontic force to their surrounding tissues, where strained cells remodel

the PDL and alveolar bone, allowing the teeth to move to new positions. The biological component reflects the nature of the anticipated clinical response and highlights the plethora of differences between patients. These physiological and pathological differences may have profound effects on the outcomes of treatment. Detailed descriptions of these conditions may be found in the library or on the internet, but in addition it is advisable to communicate effectively with each patient, and with all experts who have examined and treated the patient previously. These specialists can share invaluable information about their own observations of the patient's biological and therapeutic profile. Such details should be included in the diagnosis, and reflected in the treatment plan, which may differ from a plan that addresses only the morphological features of a malocclusion.

The continuous evolution in material and biological sciences will strengthen further the interactions between orthodontists and other healthcare specialists, leading the way toward sustainable corrections of malocclusions and craniofacial anomalies. These unfolding advances will continue to reduce the distance to the elusive target of optimal orthodontics. The common thread that unifies specialists in various disciplines is the desire to share, contribute to, and participate in efforts to improve everyone's body and spirit, a universal goal that knows no boundaries.

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2

Orthodontic Diagnosis and Treatment Planning: Collaborating with Medical and Other Dental Specialists

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Summary

Orthodontists – as specialists – are expected to be proficient in diagnosing anomalies of the face, teeth, and jaws and identifying any coexisting deviations in physiological functions and systemic pathologies. As a member of the healthcare provider system, an orthodontist should have sufficient knowledge to recognize and record the etiology of a presenting malocclusion, which may result from various systemic or local aberrations. This means that any anomalies of anatomy, physiology, and the various medical conditions that may directly or indirectly influence the orthodontic diagnosis, treatment plan, mechanotherapy, or the case's prognosis should be noted. In addition, the existing oral health conditions, and problems with the dentition, ranging from the quality and quantity of the dentition, the morbidity associated with childhood trauma, dental caries, and/or periodontal diseases, which might require close collaboration with a variety of dental specialists, should be recorded. This chapter deals with these issues and provides a framework for interaction and collaboration with medical and dental specialists based on a holistic approach to orthodontic diagnosis and treatment planning. The goal is to help the reader develop the aptitude to communicate with various healthcare specialists to undertake, reconsider, stop, or reschedule orthodontic treatment with due precautions.

Success in any healthcare profession depends largely on accurate diagnosis, formulation of appropriate treatment goals, and precise implementation. Currently, patients with orthodontic needs span a wide range of age groups, personalities, social strata, and ethnic backgrounds, with varying levels of expectations (Abu Alhaija et al., 2010). Additionally, the increasing number of adult patients means that the present-day orthodontist is faced with an array of systemic (van Venrooy and Proffit, 1985; Patel et al., 2009) as well as local conditions (Basdra et al., 2001; Altug-Atac and Erdem, 2007) that may affect both the general as well as the oral health status of the individual. It is now accepted that "it is no longer appropriate to deny elective dental or medical care to patients with diagnoses that have historically been associated with poor outcomes" (Sonis, 2004: 277). The recent medical and dental advances have made it possible for many patients with significant medical and dental disorders to be successfully managed in the orthodontic office (Lux et al., 2005), provided that the orthodontist has a sound knowledge base and is keen to interact with other medical and dental professionals (Patel et al., 2009).

Before becoming a good orthodontist, an orthodontic graduate must be a competent diagnostician and a good physician. We, as orthodontists, often make a diagnosis after taking a short medical history, complemented by a physical examination concentrating only on facial appearance (in general) and occlusion (local) alone. This approach, which is more appropriately termed "regional diagnosis," reveals the existing malocclusion, but lacks an overall perspective and the bigger picture of the medical, psychological, and pathological processes occurring elsewhere in the body gets ignored. This approach makes proper recognition of existing systemic conditions and their effects on orthodontic

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treatment difficult, if not impossible, to comprehend. In our "play safe" approach, many orthodontists refuse treatment to patients who could be treated successfully with suitable precautions and professional interaction with other medical/dental specialists. Including a module on diagnosis and management of medical conditions in orthodontic training programs is recommended, with sufficient exposure in clinical settings in multispecialty hospitals. This will allow development of an attitude that encourages a more professional approach when interacting with our medical and surgical colleagues, while recognizing and realizing our responsibilities and limitations. Up-to-date knowledge of medical problems should be combined with following proper communication protocols while referring patients to other medical and dental colleagues.

The other side of the story

Since oral health can have a significant impact on general health, dental health is often a significant concern for the medical fraternity (George et al., 2010; Yasny, 2010). Mutual referral systems are useful in these situations, with medical personnel – including specialists – referring patients with dental and oral health-related problems to dental specialists with greater zeal, provided that the specialists on both sides are confident about and comfortable interacting with each other. We should recognize that none of us can treat all the diseases of the human body. Thus, "two-way interaction" is essential for providing a better level of healthcare.

Teamwork is becoming increasingly significant and beneficial across a wide range of disciplines. The terms multidisciplinary, interdisciplinary, and transdisciplinary are often used interchangeably. They all relate to the varying degrees of involvement of multiple disciplines along the same continuum (Choi and Pak, 2006). The term multidisciplinary denotes working with several specialties but staying within their boundaries. For example, in multidisciplinary care patients are treated independently by various disciplines that share information, while the patient may be a mere recipient of care (Bernard-Bonnin et al., 1995; Choi and Pak, 2006). The interdisciplinary team denotes working between several disciplines to advance fundamental understanding or solve problems whose solutions are beyond the scope of a single discipline or area of research practice (Bernard-Bonnin et al., 1995; Choi and Pak, 2006). The interdisciplinary approach requires close communication between various disciplines and mutual respect and confidence. For instance, cleft lip and palate anomalies or craniofacial syndromes require interdisciplinary care by primarily involving craniofacial surgeons, orthodontists, clinical geneticists, otolaryngologists, speech-language pathologists, and clinical psychologists (Long and Kharbanda, 1999; Kharbanda, 2022). A transdisciplinary approach means working across or beyond several disciplines and transcending their boundaries (Choi and Pak, 2006).

Orthodontic diagnosis from a broad perspective

From a mere tooth-moving specialty, orthodontics has become a branch of dentistry with deep scientific and evidence-based perspectives for its biomechanical principles. Often, clinicians remain preoccupied with the mechanotherapeutic features of various appliances and philosophies, ignoring that teeth are a part of larger, intricately linked biological systems of the body that influence the response of teeth to mechanical stimuli.

Every patient is unique, with metabolic traits that are individually specific to them (Sidell and Kaminskis, 1975; Morrison et al., 1992; Bartley et al., 1997), even though all humans have similar basic anatomical, physiological, and biochemical features. It must be appreciated that treatment is being delivered not to an artificial set of typodont teeth but rather to vital tissues – which respond differently to the same treatment protocol under the same physiological conditions in different individuals (Ren et al., 2003; McConkey, 2004; Williams, 2008), altered physiological conditions in the same individual (Brambilla et al., 1981), and various pathological conditions (Salerno et al., 1982; Verna et al., 2000).

The craniofacial complex can be considered an organization of many small organ systems and components, such as the dentoalveolar structures, the nervous system, the muscular system, the soft tissue matrix, and the air passages. These structures are so intricately interlinked that disturbances in the physiology, anatomy, or function of any one component structure are bound to cause an imbalance in the whole craniofacial complex. This understanding should be reflected in orthodontic diagnosis and treatment planning.

Concurrently, a thorough knowledge of subjects such as anthropology, genetics, growth and development, nutrition, psychology, endocrinology, and kinesiology can help us gather critical and essential data regarding the various aspects of general health and disease. Along with this knowledge, advanced biochemical, microbiological, and radiological investigative procedures can help optimally diagnose a malocclusion, thus reducing the chances of treatment failure. In brief, a comprehensive approach toward diagnosis and treatment planning helps categorize patients according to their general health status and biological limitations, and increases the probability of a successful treatment outcome.

The first interaction with the patient

The initial examination is the most overlooked step as far as orthodontic diagnosis is concerned. Planning for an orthodontic examination should begin even before the patient visits the orthodontic office, through careful screening via a telephone conversation with trained office personnel, or through emailing the patient's knowledge of their medical history to the orthodontic office before the

scheduled appointment. This preliminary review will often highlight critical medical conditions such as endocrine, hematological, cardiac, renal, hepatic, pulmonary, and allergic disorders, as well as dental health-related conditions. Such information is vital for the orthodontist to prepare for the appointment and plan various investigative procedures and anticipated referrals, which can translate into increased efficiency and reduced time required for the screening and risk assessment of the patient. This strategy should ultimately lead to higher confidence levels and increased patient satisfaction, and lower chances of complications later during therapy.

Comprehensive diagnosis and treatment planning should start at the time of the first interaction with the prospective patient (Kharbanda, 2020). The short "look–see" examination is no longer considered adequate with the increasing number of patients with medical problems seeking orthodontic treatment. Therefore, at the first visit the orthodontist should enquire about the problems and what the patient and parents expect from orthodontic treatment (Figure 2.1) and concurrently perform an appraisal of the patient's psychological profile, as treating patients with unrealistic expectations or with extreme mood fluctuations may result in an unhappy ending (Al-Omiri and Alhaija, 2006). Following this initial scrutiny, a systematic examination procedure should be followed, starting with the craniofacial region. If the examination or the previous medical history indicates the presence of underlying pathology or abnormality, further investigations in the form of referrals and advanced diagnostic tests should be undertaken.

Figure 2.1 (a–d) A 12-year-old girl with severely compromised vision attended with her parents for protrusion of her upper anterior teeth and poor dental esthetics. She had a Class II malocclusion with bimaxillary protrusion and severe discoloration of the dentition due to fluorosis. The radiographic examination also revealed an inverted and unerupted mesiodens. The diagnosis and treatment plan in such a case must include evaluation of the patient's and parents' expectations in view of the reduced vision of the patient, who may not fully appreciate the benefits of improved esthetics following orthodontic treatment and correction of the discolored anterior teeth. It is also pertinent to elicit the intensity of concern in the patient and parents toward the discoloration and protrusion as well as the motivational factors with regard to treatment.