Orthodontically Driven Corticotomy

Tissue Engineering to Enhance Orthodontic and Multidisciplinary Treatment

Edited by Federico Brugnami and Alfonso Caiazzo

WILEY Blackwell
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To Stefania and Giulia, my family and center of gravity, for all the time that writing this book has been taking away from them.

Alfonso Caiazzo

To Antonia, my love.
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“How long will my orthodontic treatment last, doctor?”

Very often the answer to this uncomfortable question disappoints the patient and frustrates the orthodontist. In the mid-20th century many orthodontists quoted “open-ended” fees, adjusting to variance in tissue response and leaving the patient to decide when they were “finished.” But evolving practice customs and third-party fee limits have painted many 21st-century doctors into a corner, demanding standards of excellence that are often difficult to achieve on the predictable basis which one fee demands.

This is because our patients, like all biological systems, are characterized by great heterogeneity and unpredictable confounding variables. So the inflexible strictures of fixed fees often impose unrealistic expectations, and early successes must subsidize laggards and inefficient biomechanics. Fortunately, many innovative techniques have evolved to soften these blows to efficient clinical management. Some propose surgically facilitated orthodontic therapies (SFOTs), which encompass major surgery and hospitalization. More refined outpatient methods, herein referred to as Orthodontically Driven Corticotomy (ODC), have promised even greater innovations for forward-thinking professionals.

All modern incarnations of the 19th-century corticotomy share the common attribute of accelerated tooth movement if adjustments are made biweekly. But the benefits of ODC are far more important than speed alone. The benefits of Periodontally Accelerated Osteogenic Orthodontics® (PAOO®), for example, define a new era of practical tissue management by literally engineering novel epigenetic expression. The full expression of ODC also carries salutary benefits to supporting tissue, including better protection for the periodontium. This is true regardless of the biomechanical manipulation that the orthodontist might employ.

Remember that conventional but injudicious orthodontic therapy, unembellished with periodontal insight, may be hazardous to our patients’ health. We have known this since the pioneering works of Zachrisson and Alnaes (1973, 1974) and Wennström et al. (1987, 1993). Moreover, the recent disclosures of harm that disseminating gingivitis can render (Han et al., 2010) reinforce our most sobering fears. This textbook, a commendable effort by Drs Brugnami and Caiazzo, serves as an intellectual guideline of great practical merit to ameliorate
these risks and impediments to efficient care. But it also lives as an evolving document that undoubtedly will increase in value as new data emerge in this “Century of the Biologist” and as orthodontists continue to evolve as dentoalveolar orthopedists.

The simple corticotomy has, throughout its long development, also ushered in a plethora of new concepts and clinical strategies that are only now becoming understood by the dental profession. This book takes the reader to a kind of “bottom-up” perspective of orthodontic practice by conjoining “optimal force” with a contrived “optimal response.” Now, patients have greater options from which they may design their own personalized care as clinical practices become democratized in the Information Age. Indemnifying entities like governments and insurance companies can still proffer categorical “products.” Yet, doctors are now reassured that side effects like root resorption and tissue damage are minimized while the scope of practice expands to meet 21st-century challenges. With ODC all stakeholders win.

From a more scholastic perspective, this text proffers a glimpse into a kind of biological renaissance, long in coming but destined as sovereign over art. These are dramatic leaps forward which – while bemusing to the intrasigent traditionalist (Matthews and Kokich, 2013) – are, to the sensitive scientist, a fascinating trend and a compelling read. Grounded in implacably robust scientific verities, the postmodern corticotomy and its progeny – PAOO, periodontal stem cell therapy, and transmucosal perforation (perturbation) – have emerged as both a challenge to traditional orthodontic art and a solution to many of its problems. Alas, in the slow parade of scientific progress, some will always fight the tide of innovation. So Luddites and naysayers listen up.

Query. Would you buy a house from an architect who has ignored innovative civil engineering to strengthen the foundation? Of course not! And by the ancient ethical imperative, The Golden Rule, neither should we ignore the foundation of our orthodontic creations. The more immediate challenge is how to deliver the science to patients on a daily basis with practical, safe, and rewarding protocols.

This book is the roadmap to that new horizon. Specifically, the editors have assembled a worldwide consortium of scholars and translational scientists (clinicians) with a compendium of excellent cell-level science. This collection justifies a kind of orthodontic “NewThink,” attractive rational algorithms that can expand the scope of the clinical biology. Further – in deference to the clinical artisan – it fortifies traditional wire bending against the ubiquitous criticism that orthodontic art lacks a cogent biological rationale (Johnston, 1990).

This “bottom-up” approach to orthodontic care does not demand radically new practices. All ODC asks of the doctor is efficient biomechanical schemes and an open mind. Yet, it is difficult to write about clinical protocols that are to be universally appealing. This is because each clinician, with limited time, wants to learn very easily how new protocols (a) have a strong basis in science, (b) can be delivered in a safe, practical, and profitable manner, and (c) will be appealing to most patients. Those elusive goals have been masterfully achieved in this textbook.

Chapters 1 and 2 provide the reader with a general overview of ODC techniques within their historical context and discuss emerging variations that are still expanding the field of SFOT. Under this rubric of all post-modern corticotomy incarnations, Professor Ferguson, one of the strongest intellectual advocates, adds an elegant and comprehensive meta-analysis of animal model research. His authoritatively provocative insights relate ODC in a way that should please both the ethereal academic and the clinical pragmatist in all of us.

In Chapter 3 Drs Mehra and Shinwari consider how PAOO and discretely selective alveolar decortication broaden the range of orthodontic therapy. They go on to contrast these innovations with traditional orthognathic surgery where ODC procedures might serve as
reasonable alternatives to the inherent risks of hospitalization and major surgery.

Chapter 4 extends the applications of corticotomy even further and dovetails into the concepts of relative anchorage and piezosurgery. After this chapter the reader can better understand how piezosurgery might modify basic corticotomy techniques with so-called “one-sided” surgery described by Professors Dibart and Keser in Chapter 5.

Chapters 6, 7, and 8 give us a deeper understanding of the orthodontic–corticotomy synthesis in the context of basic science by exploring ODC as tissue engineering. It is this science that explains how judicious loading in the healing bone wound might facilitate orthodontic tooth movement and stable phenotype alteration.

Professors Melsen and Luzi in Chapter 9 explain how efficient biomechanical protocols must be deftly coordinated with surgical manipulation to effect an optimal outcome. With their artful pedagogical prose, these forward-thinking professors meld traditional wire bending art with their expertise in alveolus physiology. This culminates the biological teachings that the venerable Professor Melsen has so firmly implanted into the Zeitgeist of the orthodontic specialty.

In Chapter 10, Drs El-Mangoury and Mostafa investigate corticotomy-facilitated orthodontic therapy in cases of anterior open bites. Their contribution further elucidates how the parameters of traditional orthognathic surgery may need to be reconsidered in light of the nascent science that ODC promises for alveolus bone manipulation.

All these contributions have been woven into an intellectual fabric exceptionally well by the prodigious editorial efforts of Doctors Brugnami and Caiazzo. What emerges from their collaboration is the kind of book that you can place next to your office phone for quick reference between patients or read at leisure for its more profound scientific merits.

It is important to remember that the specialties of periodontics and orthodontics developed separately but are naturally indistinct in biology. They are separated only by political evolution, the microeconomic demands of private practice, and a delicate dichotomy of art and science. Yet the art of the traditional orthodontist – standing alone on ever feeble limbs – is often spoiled by delays, periodontal infection, and notoriously severe relapse. Since ODC minimizes relapse and time in treatment, it reduces the bacterial load, and thus the risks of chronic infection. In this regard, the recent revelations of significant oral–systemic interaction (Glick, 2014) make the integration of both specialties not only a biological sound decision, but also, in many respects, a professional imperative. Then why is there reluctance among recalcitrant skeptics when confronted with the word “corticotomy”? The answer is that the science has never been fully explicated from the art in a fountainhead of clinical reports. But in this book the science is revealed. And it is widely acknowledged as good science (Amit et al., 2012). Despite counterpoints that never fully fathom the best protocols, ODC in many forms is here to stay. The only question is: Who will define what is good science? …the patient? …the lawyer? …the managed care auditors and bureaucrats? …a government agency? This book takes the strong position that science should be defined from only one authoritative source: the scientist. And that scientist is you, doctor!

For the young orthodontist just starting to practice, this book asks a critical existential question: who are you, doctor …really? artisan or scientist? What will you choose to believe? Which path will you follow? Will you be the first among your colleagues to lead or one of the last to follow? ODC is certainly not your fathers’ orthodontics. But if we are to be faithful to the promise of science, then we must be willing to embrace its bountiful harvest even when traditional art objects. Will you be the first among your colleagues to exploit this opportunity or one of the last to learn? Quo vadis?, young orthodontist, quo vadis? indeed.
The editors and contributors to this text have attempted to make the following chapters faithful to the principles of translational science, steeped in the tradition of logical positivism, yet practical in execution and healthy in its payoff for patients. So temporarily suspend disbelief while these fine contributors attempt to awaken you from complacent slumber. The 21st century is knocking at the door. Read well, practice well, and above all, as legions of dental professors worldwide would entreat, Carpe Diem!

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Efficiency of treatment, expanding the scope of orthodontics, and diminishing the incidence of side effects have been the focus of many clinicians and researchers for a long time. Despite corticotomy already having been described and utilized in the last century, only recently has it gained much attention. Interestingly, we have been witnessing contrasting reactions and misinterpretations about the term, the use and its indication or advantages, causing a tremendous horizontal diffusion and an extremely low vertical diffusion around the world. That is why we felt that a book entirely devoted to corticotomy or Periodontally Accelerated Osteogenic Orthodontics® was much needed.

The term. “Corticotomy” is often confused with “osteotomy.” Corticotomy is the cut of the cortices and osteotomy is the cut through the entire thicknesses, including the interposed medullary bone between the cortices, potentially creating a mobilized segment of bone and teeth. The confusion was mainly created because the earlier concept of rapid tooth movement was based on bony block movement in corticotomy techniques. Paraphrasing leading author of Chapter 1, Dr Neal Murphy would say, “This kind of surgery is not intended to ‘rearrange anatomical parts’ like so many Lego® children’s toys. Parts rearrangement is within the scope of orthognathic osteotomies. Corticotomy-facilitated therapy does not create anatomical fragments or separate ‘parts.’ Corticotomies re-engineer physiology; they seek to re-engineer epigenetic potential in both the basic physiology of healing and ultimate morphogenesis at the molecular level of DNA and (endogenous and grafted) stem cells.” Tissue engineering is the sum of “tissue” (a collection of cells for a common purpose – cf. organ, a collection of tissues for common function; e.g., the stomach, the face, the periodontium) and “engineering” (marshaling natural forces and manipulating them to a predetermined design – cf. civil engineering turning water flow to mechanical energy by changing the design of river courses and then changing the mechanical energy of fluid dynamics, via a turbine, into the form of electrical energy before an electrical engineer manipulates it to visible wave lengths of the electromagnetic spectrum in lasers. Finally, we turn visible electromagnetic flux, dissipate it into tissue, changing the design of oral tissue and, using the osteopenia it induces, changing the form. In a much more, less ablative way, with PAOO we take the natural forces of biological wound healing and turn them into a
new phenotype design). The Wilcko brothers were the first to promote that the movement does not result from repositioning of tooth–bone blocks, but rather from a cascade of transient localized reactions in the bony alveolar housing leading to bone healing, and modified the technique by adding bone grafting and drastically changing the rationale of its use. That is why we consider them the fathers of modern corticotomy.

Corticotomy-facilitated orthodontics (CFO), rapid orthodontic decrowding, modified corticotomy, alveolar corticotomy, selective alveolar corticotomy, speedy surgical-orthodontics, accelerated osteogenic orthodontics, selective alveolar decortication, Wilckodontics, corticotomy-assisted decompensation, augmented corticotomy, surgically facilitated orthodontic therapy, and corticotomy-enhanced intrusion are some of the names of procedures that all originate from their new approach and definition. In most of this book, PAOO and corticotomy will be used interchangeably, although the latter clearly distinguishes from the former because of bone grafting.

The use and indications. Considering corticotomy just as a method to accelerate orthodontic movement would be limitative. The most interesting effect is the osteogenic potential. When combined with bone grafting, this technique may help to expand the basal bone. This will clinically translate into at least two main positive effects: (1) more space to accommodate crowded teeth and then less extraction of healthy premolars in growing patients; (2) a thicker, more robust periodontium, which may help to prevent recessions during or after orthodontic movement. The concept can be stretched to the point that, according to Williams and Murphy, “the alveolar ‘envelope’ or limits of alveolar housing may be more malleable than previously believed and can be virtually defined by the position of the roots. This is the beginning of bone engineering in orthodontics, and the dental surgeons and the orthodontists should define themselves as dentoalveolar orthopedists, while embracing this new philosophy of treatment. The emphasis on bone engineering during orthodontic tooth movement promises much more than an alternative protocol to increase speed of orthodontic treatment. The orthodontists, with their surgical partners, can modulate physiological internal strains (similar to those of distraction osteogenesis in long bones) to define novel and more stable alveolus phenotypes”; this would minimize not only premolar extractions, but also orthognathic surgery morbidity (such as surgical palatal expansion, for example).

Diffusion of corticotomy. The science that studies the principle of innovation and change defines “technology transfer” as all activities leading to adoption of a new product or procedure by any group of users (http://www4.uwm.edu/cuts/bench/princp.htm).

“New” is used in a special sense, meaning any improvement over existing technologies or processes, not necessarily a chronologically recent invention. Technology transfer is not simply dissemination of information and passively awaiting its use. Technology transfer is an active term. It implies interaction between technology sponsors and users and results in actual innovation. We should also distinguish between innovators or early adopters and late adopters.

Innovators are individuals or groups who are willing to progress by adopting “new” methods, products, or practices not widely in current use. They are a key to the diffusion of innovations because they provide practical evidence that an innovation actually works, and this is important to later adopters. These users may frequently create their own innovations in response to specific problems that they face. We should also define diffusion (the spread of an idea, method, practice, or product throughout a social system), horizontal transfer (the movement of information on technology between innovators (peer-to-peer) within an organization or between similar organizations), and vertical transfer (the movement of information on technology from innovators to
late adopters of an organization or system of organizations).

Corticotomy has been increasingly employed with great success worldwide and therefore gained a tremendous “horizontal diffusion.” From South America to Africa, from the Middle East to the Far East, from Europe to North America, different groups of scientists/clinicians have been working and publishing on the subject (extensive horizontal diffusion). In contrast to this worldwide distribution, the highest percentage of orthodontists in North America are either ignoring or skeptical and fail to present it to their patients as a viable and valuable alternative (lack of vertical diffusion).

There are different reasons to explain such a difference in diffusion, other than natural resistance of people and organizations to change:

1. The innovation is not disseminated. Given that the “innovation” is truly innovative, one of the most important driving factors is the economical one. For example, most of the innovation in dentistry in the last 30 years, from implants to membranes, to clear aligners or straight wire, have been “encouraged” by suppliers and manufacturers. It’s the same as in the pharmaceutical business: any revolutionary drug to cure a rare syndrome would suffer a difference in diffusion compared, for example, with Viagra® or bisphosphonates or statins.

2. The innovation is disseminated to the wrong people. The information is not referred to the proper person or somehow gets lost on the way.

3. The innovation is not understood by the potential user. Most of the time this is created by a superficial knowledge of the technique or misinterpretation, lack of homogenous terminology, and underestimation of potential benefits.

We decided then to put together a “dream team” of corticotomy, with contributors from many different countries, representing directly or indirectly four of the five continents, hoping to help the application of this revolutionary technique and innovative philosophy of treatment.

Federico Brugnami and Alfonso Caiazzo
About the companion website

This book is accompanied by a companion website:

www.wiley.com/go/Brugnami/Corticotomy

The website includes:

- Demonstration videos of surgical procedures featured in the book
- PowerPoint slides of all figures and PDF versions of all tables for downloading
Preface

All Men by nature desire knowledge.

Aristotle

This chapter attempts to create an intellectual matrix within which other contributors writing about orthodontically driven corticotomies – also known as surgically facilitated orthodontic therapy (SFOT) – find both justification and inspiration with a modicum of practicality. The corticotomy, a selective alveolus decortication (SAD) of the alveolus bone, is but one in a family of related procedures encompassed by the inchoate field of SFOT. This treatise, by the very nature of the subject, focuses more on science than orthodontic art. And that science is orthodontic (bone) tissue engineering (OTE).

Yet, the emphasis on bone engineering during orthodontic tooth movement (OTM) promises much more than an alternative protocol or new clinical gadgetry. This chapter, in the context of an historical review, presents an evolution (and a clash) of ideas to reveal universal biologic principles. It is these principles, these transcendent truths, that should be applied to particular clinical events in a meaningful and rewarding manner. The student of SFOT should not indulge in mindless dedication to one technical recipe without understanding the specific biologic mechanisms and therapeutic objectives that define it.

The ideas and procedures of SFOT herein are increasingly being employed with great success worldwide despite the natural impediments of healthy skepticism and unintentional misrepresentation. Importantly, this global popularity is forging a new identity for those who wish to embrace it. Twenty-first-century orthodontists, periodontists and other surgeons are becoming...
international citizens endowed with skills and intellects of global scientists, forming a mastermind that is liberated from “brick and mortar”, national, or even regional biases. We comment on that emergent event as doctors who have participated in a nascent science; we witnessed its birth, watched it develop, and remain ever fascinated by it. The contents of this book lend credence to that new identity and the authors personify the spirit of free inquiry that sustains it. Yet, in our zeal to share knowledge, we posit most humbly that we are merely the messengers.

INTRODUCTION

Conceptual issues

The title of this chapter is not a question; it is an existential choice. Because the history of the corticotomy presents thematic questions much more profound than where one should make surgical cuts, some explanation of this chapter’s syntactical style is in order. The historical journey of the orthodontic specialty reflects a similar kind of thematic development replete with controversy. Throughout that rocky sojourn, two contentious themes have always emerged. The first is whether the essence of orthodontic practice is art or science. The resolution of this dichotomy is that orthodontics is neither and both. Art and science are merely two different but complementary perspectives of the world. So conflict between these two worldviews is actually quite illusory. It is resolved only by realizing that arts and sciences are merely tools, intellectual instruments with which we achieve a nobler mission: our humanitarian endeavor of caring for others. Still, the two classic perspectives always prevail and must be constantly rebalanced: humanistic art as the ends, science as the means.

The second theme, a perennial conflict between extraction and non-extraction protocols, is more philosophically relevant to our topic. One of the great advantages of SFOT is that alveolar bone can be reshaped to accommodate an idealized dental arch rather than modifying a dentition to “inferior bone.” An historical drag on this progressive trajectory is the assumption that the alveolus bone is immutable. It is not; the alveolus bone is remarkably malleable.

So, in a way, the new realization that the alveolus bone is malleable and the ability to “build a better bone” renders the extraction–expansion debate somewhat moot. With a “new biology” of orthodontics this historical debate has been rendered simplistic and false, just as epigenetics has rendered the nature–nurture debate an anachronistic dichotomy in the face of evolutionary sciences.

Our historical review cannot dictate where art ends and science begins in the mind of each orthodontist, for as every flower is beautiful, yet every flower is unique. And the sensitive orthodontist takes each individually unique “flower” to full bloom in its own season using both art and science. Likewise, one cannot dictate to every orthodontist exactly when extractions in particular should or should not be prescribed. One can only disclose a wider scope of therapeutic options, to achieve high-quality care. And, to many, quality is an event; namely, the coincidence of doctor talent with patient expectations in a universe of humanistic but rational achievement. This is the tacit mission of this textbook and its selfless contributors.

When dealing with facial esthetics the artistic imperative is undeniable and the decision to extract or not to extract reflects individual interpretations of timeless principles. Most art is intuitive. Yet even art – namely, impressions, culturally influenced in the aggregate and subjectively sensed in the individual – is not totally beyond the reach of scientific scrutiny. And, for better or worse, scientific scrutiny must always be the abiding companion of the 21st-century doctor. This is because contemporary practice, whether engaged with biological principles or indulged in psychosocial imperatives, operates in a postmodern world that demands demonstrable scientific proofs where we find them or (at least) compelling biological rationales where
we can divine them. History reveals the former and justifies the latter.

In this chapter, our methods are innovative, and admittedly somewhat polemical. We do not merely report a litany of events and experimental results. We cleave existing basic science to pertinent clinical data and synthesize them with traditional protocols. This hopefully will fortify what is done right by explaining it and provide alternatives to what can go wrong by explicating errors from their historical context.

When innovative science is seen through the lens of historical context, two important revelations occur. First, sophisticated insights of nuance are clarified (e.g., bony block movement versus enhanced physiology); and second, some new ideas are revealed simply as “old wine in new bottles” (normal healing, the regional acceleratory phenomenon – see 1983: Frost and his regional acceleratory phenomenon). This chapter will undoubtedly serve some old wine, but that insight does not diminish its worth. The historical context merely legitimizes the insights as more salient and timeless.

Through the gauntlets of criticism and the civil internecine bickering that often characterizes our specialties, it is curious indeed how truth emerges. Yet it is important to note that an assiduous intellectual analysis, emancipated from the strictures of dogma, and inspired by intrepid pioneers who have preceded us, is what sets the tone for this chapter and perhaps even the textbook itself. Query: is it nobler to suffer the indignities of dogmatic tradition or bear the yoke of exciting innovation? The former is safe, but the latter is tantalizing since it unravels the nettlesome enigmas of biology.

We must choose the latter despite the fact that unraveling mysteries is politically and philosophically risky when it exposes hues of uncomfortable truth. But the explication of truth is our deontological duty, because we have the power to control the welfare of other human beings, and that duty imposes a fiduciary standard more exalted than the “treatment to the norm (average).” Axiomatic to all clinical endeavors is the view that treating patients is a privilege, not a right, and a privileged position demands excellence, not mediocrity.

**Dedication**

John Donne reminds us that “no man is an island, entire of itself,” and this chapter is a collaborative exemplar of that reality. Yet, the exciting frontiers of oral tissue engineering herein belong to neither our venerable teachers alone nor the seasoned clinicians who wrote this chapter. Rather, the future and our efforts are dedicated to those who will enjoy a longer tenure of equity in the specialty than we. This chapter is dedicated to them: the young idealists still seeking a place in the pantheon of clinical science. *Arete*

**The nature of the phenomenon: intuited early, defined late**

**Diction and definitions**

For the purposes of expediency and ease of reading, certain terms will depart their strict scientific definitions to be used in a liberal sense. The terms “corticotomy” and “SAD” will be used synonymously, and “mobilization” will be interchangeable with “luxation,” meaning the physical jarring, fracturing, or cracking of bone. Surgically facilitated orthodontic therapy means any cutting of tissue that makes orthodontic treatment work better or faster. Other terms will submit to strict definition.

**From osteotomy to corticotomy to tissue engineering**

When reviewing the history of corticotomies one discovers that it originated in attempts to minimize the harsh side effects and risks of
segmental osteotomy. And this history is complicated by the fact that early writers used the terms osteotomy and corticotomy synonymously. So much of the early literature is vague and prone to misinterpretation. An osteotomy starts with a linear decortication of bone and ends with a physical movement of a section of bone the way one might break a twig from the branch of a tree. Thus, “mobilization” is a kind of purposeful fracturing of bone, sometimes literally done with a mallet and chisel to move physical parts, whereas a corticotomy is limited to the initial incision to modify physiology without luxation or fracture. When studying SFOT one must keep in mind the fundamental effects and esoteric mechanisms that facilitate the phenomena.

These effects, “observed” in the mind of the surgeon during the operation, occur subclinically at the tissue and cell levels. They are less clearly defined than clinic-level gross anatomy, a level to which most orthodontists are accustomed. Therefore, new modes of thinking must occur that could not have been appreciated by the specialty’s earlier advocates. However, these histological mechanisms may have been singularly intuited by John Nutting Farrer (1839–1913) as early as 1888. He was referring to orthodontic tissue effects from a “whole alveolus bone” perspective when he wrote (emphasis added):

> The softening of the socket breaks the fixedness or rigidity of the tooth leaving it comparatively easy to move, either by resorption of the tissues or by bending of the alveolar process or both.

**Histophysiology of orthodontic-driven corticotomy**

The “whole-bone perspective” is a new way of looking at alveolar bone reactions to orthodontic forces that goes beyond the narrow perspective of the periodontal ligament or a focus on the midpalatal sutures. This “New Think” attempts to preclude retruded profile risks of extraction therapy. Williams and Murphy (2008) documented, with unequivocal biopsy images, that lingual forces can stimulate labial subperiosteal (compensatory) osteogenesis by showing samples of labial woven bone where the alveolus was expanded slowly from the lingual aspect. It should be noted, however, that any claim of permanent bone alteration with Williams and Murphy’s appliances or surgical phenotype re-engineering cannot be made before 3–4 years into the retention stage when the calcification is complete to an osseous “steady state” (dynamic equilibrium). Inherent in Williams and Murphy’s philosophy is the assumption that emerging esthetic standards are shifting toward “full facial” esthetics quite different from the classic retruded profile of Apollo Belvedere (Angle’s esthetic standard). This philosophy is not only compelling because of his biopsy evidence of alveolus development, but also because of its natural appeal to good common sense.¹

The osteogenic effects demonstrated by Williams and Murphy (2008) in the alveolar subperiosteal cortices in nonsurgical cases capture exactly the histophysiology of corticotomy surgeries. Surgery simply elicits the phenomenon more dramatically and faster. The theoretical concept had been alluded to previously and was most recently expanded in the excellent textbook by Melsen (2012), where it refers to a “…change in surface curvature of the alveolar walls.” All contemporary orthodontists should read this most enlightened summary of basic alveolar osteology to fully understand bone strain in all patients (Verna and Melsen, 2012). This “whole-bone” perspective posits the alveolus bone, cf. alveolar “process,” as a separate operative organ independent of its subjacent corpus. As the whole bone is orthodontically bent, each osteon is deformed. The “peri-orthodontic hypothesis” (Murphy, 2006) contends that this bends protein molecules and DNA, opening obscure binding sites
on important molecules to elicit an epigenetic perturbation and redesigning the morphogenesis to a novel phenotype unique in alveolus in shape, mass, and volume. The value of this new perspective is that it conforms well with contemporary basic biological sciences, particularly molecular biology and epigenetics.

In this regard, alveolar subperiosteal tissue and periodontal ligament act no differently than the periosteum and endosteum respectively in any long bone (Figure 1.1).

Therefore, a lot of recent medical and basic orthopedic science can be transferred to and from alveolus bone science. This phenomenon, facilitated by corticotomy protocols, we believe may be employed to reduce the degree of clinical relapse that still plagues orthodontics after 100 years of clinical trial and error.

Standard orthodontic protocols, without surgery, cannot overcome the natural tissue “canalization” that resists phenotype change (Waddington, 1957; Siegal and Bergman, 2002; Slack, 2002; Stearns, 2002).

**Cell-level orthodontics**

Bone cells, and homologues in other tissues as well, sense changes in their mechanical environments, internally throughout the cytoskeleton and externally through focal adhesions to the extracellular matrix (Benjamin and Hillen, 2003; Murphy, Verna and Melsen, 2012). This area of cell-level biomechanics was essentially beyond the control of most orthodontists, who relied instead on gross anatomical and clinical events to intuit cellular activity. With

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**Figure 1.1** It is important to realize that SAD and particularly PAOO/AOO can change the configuration of the alveolus bone regardless of the form of the underlying maxillary or mandibular corpus. This apparently occurs by subperiosteal appositional osteogenesis stimulated by shear compression and shear tension on the facial and lingual cortices. In this respect, the periodontal ligament acts like endosteum in long bones. This realization resolves the ostensible conflict with the medical orthopedic claims that pressure is osteogenic and tension has osteoclastic effects, in contrast to the traditional orthodontic pressure–tension hypothesis that has been criticized so much in recent literature. This perspective does not deny that ischemic necrosis occurs in the periodontal ligament, but merely expands the biological concept of orthodontic histology beyond the ligament. This resorption on the so-called “pressure” side may be more related to osteogenic shear tension (−) in the cribriform plate similar to long bone homologues. On the so-called “tension” side, an increase in concavity of the cribriform plate is evident causing shear compression (+), which is osteoclastic in long bones.
the introduction of tissue engineering concepts and a revival of corticotomy-facilitated orthodontics, a new interest in cell- and tissue-level phenomena has appeared in the dawn of the 21st century.

Induced mechanical stimuli not only change the internal cytoskeleton but – by epigenetic perturbations – can determine internal stereochemical and ultimate morphogenesis. To the extent that wound healing recapitulates regional ontogeny, orthodontic modulation of the healing bone wound can engineer a new phenotype ideally suited for an ideal dental alignment and dental arch juxtaposition even to the point of modifying the need for orthognathic surgery. The alveolus bone, which lives, thrives and dies by virtue of its functional matrix (Moss, 1997), the dental roots, are especially responsive to therapeutic intervention in this regard because of behavioral imperatives identified by Wolff’s law and Frost’s “mechanostat” model (Frost, 1983).

What skeletal muscle can do to bone morphogenesis at the gross anatomical level is similar to the effects of microstrain at the cell/tissue, whether that be hypertrophy, hyperplasia, or atrophy, thus demonstrating that engineering bone morphogenesis is a threshold phenomenon; that is, too much or too little is dysfunctional. It should be remembered that the influences of mechanical stimuli at the cell and tissue levels, mechanobiology, lie not only the domain of bone alone. Indeed, the even pathoses of atherosclerotic cardiovascular disease are directly related to mechanobiological changes in vessel walls. With modern analytic methodologies and a burgeoning body of science, too extensive for the scope of this writing, responses to all tissue can now be studied and actually modulated, be they integumental or neuronal, mucosal or bony. This is the essence of tissue engineering science. Thus, orthodontic scientists have a legitimate equity claim in mechanobiological fathoms as well. So, there is no reason they should not be involved considering the critical importance of their domain, the face of a human child.

The study of cell/tissue-level orthodontic therapy, especially the nature of genetic expression evident in healing bone wounds, suggests that orthodontic relapse can be seen as a simple reversion to original phenotype, regardless of the method used. That is why some SFOT has been proven to be a popular – in some cases manifestly superior (Dosanjh et al., 2006a,b; Nazarov et al., 2006; Walker et al., 2006a,b) – and professionally acceptable adjunct to traditional orthodontic therapy. The evidence of efficacy that this innovation enjoys lends both clinical quality and stability to OTM, justifying it as a reasonable therapeutic enhancement. There are advantages and disadvantages with both conventional OTM and SFOT, and it is only fair to patients that they be made aware of all treatment alternatives. At the clinical level, SAD is termed the Periodontally Accelerated Osteogenic Orthodontics™ (PAOO) technique or the Accelerated Osteogenic Orthodontics™ (AOO)³ technique only when a bone graft is added, and these two terms can be used interchangeably. The lead author prefers to use PAOO when there is periodontal involvement and AOO when the periodontium is healthy.

Experience suggests that, in most cases, demineralized human bone graft or viable stem cell (allograft) therapy (SCT) should provide a predictable outcome. A non-surgical derivative, trans-mucosal perforation (TMP), (Murphy, 2006) can be employed when flap surgery is not indicated in small areas with excess bony support.

A HISTORY OF THE ORTHODONTIC-DRIVEN CORTICOTOMY (OVERVIEW)

Origin of the concept

Cano et al. (2012), as with other authors, generally attribute the first published surgical method to facilitate orthodontic therapy to Cunningham (around 1894) after his lecture in Chicago the previous year. While having
some rudimentary characteristics in common with modern corticotomies, close scrutiny of Cunningham’s SFOT procedure suggests it was really a luxated segmental osteotomy. Cunningham’s singular goal of making teeth move faster has since evolved to more global objectives, and variations on the corticotomy theme have spawned interesting incarnations throughout the 20th and 21st centuries in many different countries and cultures.

These variants evolved in a progression of surgical refinements designed to (a) accelerate OTM, (b) limit the quantity and pathologic potential of the inevitable bacterial load, (c) enhance stability, and (d) reduce the morbidity of orthognathic alternatives. As Cunningham’s crude luxating osteotomy evolved, the term “corticotomy” emerged in the clinical lexicon with its approximate and more disciplined synonym, SAD. So both terms may be used as roughly synonymous for practical purposes.

But it should be noted that SAD with OTM will not grow new bone mass. In fact, in an adult, steady-state alveolus treatment may ostensibly slightly reduce alveolar bone mass. This is described in the non-surgical orthodontic literature as “moving bone out of the alveolar housing.” So applying Cunningham’s derivatives indiscriminately may indeed result in a net loss of supporting bone. This dilemma was solved by altering phenotype and creating additional bone de novo (Figure 1.2). Developing bone de novo has graced orthodontics exclusively through the prodigious efforts of many doctors in the Wilckodontics research groups, which are represented academically at Case Western Reserve University (Cleveland, OH, USA) by the second author. When grafted demineralized bone matrix (DBM)4 (circa 1998) and viable cell allografts entered the SAD protocol, the thresholds of bone tissue engineering (Murphy, 2006) and SCT (Murphy et al., 2012) were breached. This subsequently defined the dentoalveolar surgeon and orthodontist as partners in surgical dentoalveolar orthopedics and alveolar osteology.

New ideas often do not fit easily into old paradigms (Kuhn, 2012), so a new Weltanschauung5 (Freud, 1990) coined “NewThink”, must be embraced to mark a clear distinction between the philosophy behind new orthodontic-driven corticotomy protocols (Pirsig’s dynamic quality) and traditional orthodontic art of wire and plastic bending (Pirsig’s static quality6).

The SFOT we describe here purposely executes OTM through a healing bone wound or bone graft eliciting a purposely delayed wound maturation. This occurs by perpetuating a natural bone “callus” or osteopenia until all the teeth are ideally aligned, coordinated, and detailed. This kind of surgery is decidedly not merely a variation of a basic surgical theme of the manner in “rearranging anatomical parts” like so many Lego® children’s toys. Parts rearrangement is the stuff of orthognathic osteotomies. In stark contrast, the corticotomy-facilitated therapy does not create anatomical fragments or separate “parts.” Corticotomies re-engineer physiology. Specifically SFOT, SAD, PAOO/AOO and TMP seek to re-engineer epigenetic potential in both the basic physiology of healing and ultimate morphogenesis at the molecular level of DNA and (endogenous and grafted) stem cells.

**Early concepts: German pioneers**

While Cunningham’s procedure seemed bold to many American orthodontists, it soon became popular in the German scientific community. Cohn-Stock (1921), citing “Angle’s method,” removed the palatal bone near the maxillary teeth to facilitate retrusion of single or multiple teeth, and a host of German Zahnärzten followed his lead. Later, Skogsborg (1926) divided the interdental bone, with a procedure he called “septotomy,” and a decade later Ascher (1947) published a similar procedure, claiming that it reduced treatment duration by 20–25%.
As good as it may appear, the scientific literature of the 20th century seems to have missed the central purpose of SFOT, SAD and PAOO/AOO, and TMP. This illustrates a social phenomenon where older, more experienced but doctrinaire, clinicians see innovation not in the context it promises, but rather in the context of the status quo. This is an unfortunate but common event seen best in retrospect. This bias and the lack of modern biological standards is the reason why some literature of this period is merely anecdotal, dismissive and often

Figure 1.2 (1a) Comparison of SAD with (PAOO/AOO) and without a bone graft demonstrating the necessity for grafting when insufficient bony support is evident in adults. The figure shows the pre-treatment high-resolution computerized tomography (CT) scan (accurate to 0.2 mm) of the lower arch of a female, age 39, prior to having circumscribing corticotomy cuts performed both labially and lingually around the six lower anterior teeth. Note the arch length deficiency (overlap crowding), the pronounced crestal glabella, and the distance between the crest of the alveolus and the corresponding cemento-enamel junctions (CEJs). Clinically, the circumscribing corticotomy cuts resulted in the appearance of outlined “blocks of bone” connected by medullary bone. The total treatment time for this case was 4 months and 2 weeks with eight adjustments appointments. (1b) At 1 month retention the integrity of the outlined “blocks” of bone appears to have been completely lost and the layer of bone over the labial root surfaces appears to have vanished. In reality, this layer of bone has undergone demineralization as the result of a normal osteopenic state (RAP); the soft tissue matrix of the bone remains but is not visible radiographically. This is why radiographic assessments of expansion cases before 3–4 years in retention, while interesting in the short term, are premature for final policy conclusions. This demineralized matrix was carried into position with the root surfaces (bone matrix transportation). (1c) This shows the high-resolution CT scan at 2 years and 8 months retention. Note that the layer of bone over the root surfaces has only partially reappeared due to the remineralization of the soft tissue matrix. This suggests that there may have been a net loss of bone volume in this adult. In adolescents this is not seen. Owing to a greater regenerative potential there seems to be a complete regeneration of bone after SAD. (2a) This shows a high-resolution CT scan of the lower arch of a male, age 23, prior to circumscribing corticotomy cuts being performed both buccally and lingually around all of the lower teeth with a large bone graft placed over the corticotomized bone. Note the paucity of bone over the buccal root surfaces. The total treatment time was 6 months and 2 weeks with 12 adjustment appointments. (2b) At 3 months retention the labial root surfaces are now covered with an intact layer of newly engineered phenotype appropriate for the new position of tooth roots (the functional matrix of the bone). The pre-existing paucity of bone over the lingual root surfaces has been corrected in the same manner so that the roots of the teeth are now “sandwiched” between intact layers of bone both buccally and lingually. There has been a net gain in bone volume. (2c) At 2 years and 8 months retention the increase in the alveolar volume has been maintained. These data argue for PAOO/AOO in non-growing orthodontic patients where dental arch expansion is considered.