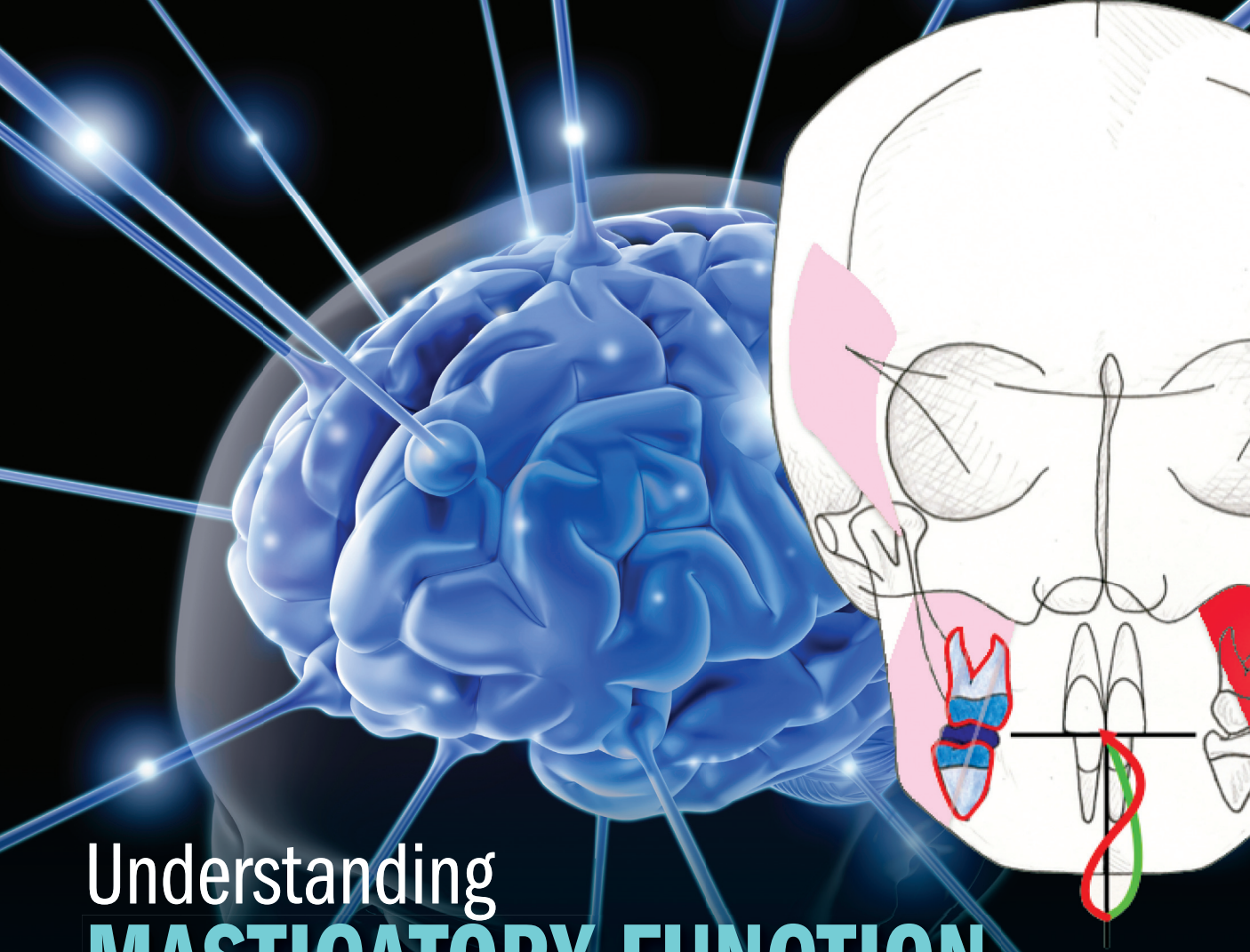

Understanding MASTICATORY FUNCTION in UNILATERAL CROSSBITES

Maria Grazia Piancino and **Stephanos Kyrkanides**

WILEY Blackwell

Understanding Masticatory Function in Unilateral Crossbites

For my father and mother,
who taught me about intellectual integrity,
which is the cornerstone of this book.

For Stefano and Federica, for putting up with such a "busy mom."

MGP

Understanding Masticatory Function in Unilateral Crossbites

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Foreword

This book's uniqueness lies in the fact that it studies malocclusion from a gnathological viewpoint, in terms of both diagnosis and treatment. The study of masticatory function includes gnathological principles that allow us to understand the functional aspects of malocclusion conditions and their effects on the entire stomatognathic system. A gnathological approach helps us understand the importance of selecting and applying treatments which respect overall physiological wellbeing.

Indeed, it is only through balanced and harmonious function that a developing system may grow healthily from a neurophysiological perspective, avoiding impairment and maintaining these results constantly throughout adulthood. Therefore, the final goal of early orthognathodontic treatment is to achieve (via the teeth) a rebalancing of function by following gnathological principles. The study of theories forwarded by respected scholars (from Gisi onwards) of the structure and function of the masticatory system and craniomaxillofacial area was extremely important for us.

During our studies we had the chance to understand the works of, as well as spend time with, B. McCollum, Ch. Stuart, H. Stallard, and P. K. Thomas (nicknamed "the immortals of Loma Linda University"), along with R. Lee, S. P. Ramfjord, T. Lundeen, and B. Jankelson. A special mention goes to R. Slavicek of the University of Vienna and A. Lewin of the University of Witwatersrand in Johannesburg, South Africa. The ideas and teachings of these scholars (on whose work our own is founded) were fundamental in the writing of this book about crossbite, thanks to their smart understanding of the risks and collateral effects as well as neuromuscular implications of the condition.

This is a matter studied and discussed by many but still deserving of further research, owing to the important and irreversible gnathological implications that we have learnt to identify thanks to the aforementioned experts. The knowledge gathered by research into mastication and then applied to the use of orthognathodontic devices before/after treatment has been essential in understanding the effect of occlusion on chewing cycles and the importance of respecting gnathological principles when selecting therapies.

The understanding and respect of these principles allowed the perfection over time of a therapy that for many years gave even better results than we could have predicted. Thanks to the study of masticatory function, many of these results became clearer, and they are described in this book in a precise and logical way (despite the complexity of the topic).

The project was not easy, and is the result of many years of research into the fields of orthognathodontics and masticatory function. I hope, above all, that this book can spark a change, a move towards a gnathological approach in the diagnosis and treatment of malocclusions, in light of the fact that the true goal of a medical dentistry field like orthognathodontics should be the functional balance and harmony of the stomatognathic system.

Pietro Bracco
University of Turin
Italy

Preface

Masticatory Function as a Reference Point

The study of malocclusion conditions and their relationship with masticatory function is of interest for the medical dentistry and the medical field in general. If one considers that malocclusions appear during the years of growth (i.e., during the psychophysical development of a child), the complexity and importance of the matter is clear. Owing to the difficulty even today of acquiring reliable studies and tools, the orthodontic field is more attracted and inundated with mechanical theories and related technological innovations that too often focus on dental shifting *tout court* without considering the functional outcomes.

Masticatory function is one of the oldest and most important phylogenetic functions for humans, both during childhood development and in adulthood, right through to old age. It requires precise coordination between dental occlusion, masticatory muscles, joint structures, and motor control. One of the malocclusions that undoubtedly affects mastication, with irreversible consequences once childhood development is complete, is that of crossbite.

This book focuses on the study of masticatory function, both in the event of physiological occlusion and in cases of pre and posttreatment of unilateral crossbite malocclusion, with descriptions and analysis of the clinical features of masticatory irregularity. This field is still considered rather as the "poor relation" of medicine and medical dentistry, in that it is rarely studied and often sidelined. However, in this day and age for most developed countries, a healthy and balanced masticatory function is fundamental in contributing to a good social life and relations and combating stress.

The best-known "players" in mastication are the teeth. Teeth are phylogenetic ancient structures and may no longer be a vital organ of survival for humans, as they are for animals. They still show very precise neural connections and are essential in terms of optimal physiological functioning. In other words, balanced dental occlusion and healthy masticatory function play an important part in enhancing our quality of life. Certainly, the study of mastication as described here is closely linked to orthognathodontic diagnoses and treatment.

Three experts have guided me in said study, without whom this research would never have taken place. I owe them my eternal esteem and admiration:

Arthur Lewin (University of the Witwatersrand, South Africa), a true friend, who ignited the first spark of an idea for this research project with his teaching on the clinical significance of chewing pattern and his open-minded approach that went beyond the traditional mathematical–statistic constraints of masticatory study.

Giuseppe Anastasi (University of Messina, Italy), with whom I shared some of the most exciting moments of the research project. Thanks to his intelligence, open mind, and determination, the molecular and functional magnetic resonance imaging (fMRI) proof of gnathographic and electromyographic clinical results of mastication were collected. He passed on to me his enthusiasm for the study of neural control, without which it would be impossible to understand masticatory function.

And last but not least, Pietro Bracco (University of Turin, Italy), my mentor forever, from whom I learnt the gnathological rules of coherent and physiological orthognathodontics. His clinical imprint has been fundamental both in the research process and in my professional and teaching life.

I owe these three men my sincere gratitude for having taught me to reason in physiological and gnathological terms (i.e. in terms of masticatory function), an approach, which lies at the base of this book.

A Consistent Reasoning from Diagnosis to Therapy

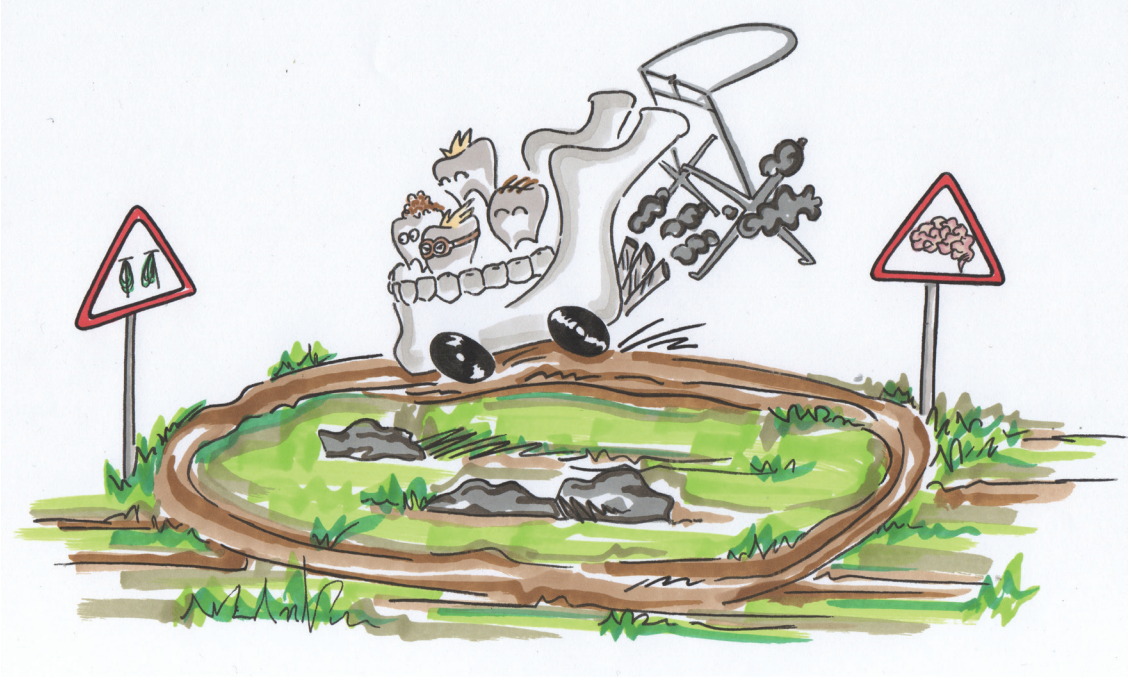
The book is divided into two main parts. The first is dedicated to mastication, its understanding and clinical importance of research results achieved with electrognathography and electromyography over years, and confirmed unequivocally by histological and morphology (as well as fMRI) studies of the masticatory muscles. The second, based on the results of the first, is dedicated to actions and effects and, above all, to functional and gnathological reasons for the use of the Function Generating Bite appliance, which corrects not only teeth, but especially masticatory function, avoiding basal and dental traumatisms and respecting biology and physiology of the structures.

The aim of this book is to give the reader (students or doctors or enthusiasts) a physiological and biological overview of the stomatognathic system, evidence-based on reliable scientific results and, for the first time, a consistent reasoning from diagnosis through therapy. This means that, to respect the biology and physiology of the stomatognathic system, structural and denta traumatic therapies are not coherent while the proposed treatment is established on the basis of functional and gnathological principles. To acquire a new approach to the subject, it is necessary (as always) to maintain an open mind and make a small effort to understanding and memorizing the various features – this effort will be amply repaid by the acquired learning of a logical sequence from diagnosis to therapy, also with useful practical aspects.

To sum up, knowing that the stomatognathic system is a vital factor in the quality of life for each and every one of us, it is our hope that this book will introduce a truly new approach to "curing" (in medical terms) one of the most important district of the human body for a balanced living.

Maria Grazia Piancino

How to Use This Book



This book brings together the lecture notes of courses imparted to students at the postgraduate School of Orthognathodontics and at the degree course in Dentistry and Prosthodontics at the University of Turin, Italy. It is the result of more than 20 years of study and research, with the contributions of students, patients, professionals, bio-engineers, and dedicated scholars. The original source material (i.e., the lessons themselves) has influenced the writing of this book, and it is the pictures and diagrams that lead the reader through a voyage of discovery exploiting the visual memory where the final objective is understanding the importance of therapeutical respect for the stomatognathic system's physiology, biology, and memory function. We believe that the use of visual memory and progressive "familiarity" with the subject (as opposed to vice versa) helps make this book a simple aid to study, and a source of immediate and stimulating comprehension and reference of the complex subject of masticatory function. Its links to growth and orthognathodontics represent one of the most fascinating areas of medicine and dentistry.

Acknowledgments

Many people have contributed, both directly and indirectly, to this book and research.

I would like to give a special mention to Dr Teresa Vallelonga (University of Turin, Italy), not only for the enormous amount of work she contributed to the production of this book, but also for the professional support and effort constantly demonstrated during the long years of research that ran parallel to the book's creation. I greatly appreciated her determination even during very busy times; this book will remain permanently linked to the two mascots, Maria Chiara and Giacomo.

I am equally grateful to my co-author, Stephanos Kyrkanides (University of Kentucky, USA), who is my "overseas" support – his European roots combined with his US professional training and incredible mental openness were fundamental for the explanation of such a complex topic as mastication in orthognathodontic terms, and for the realization of this book. I owe him my sincere gratitude.

Special thanks go to Prof Ezio Ghigo (Univeristy of Turin, Italy) for his support and mentorship in transmitting to me an enthusiasm for the idea of this book, which proved so necessary to me during its writing. A huge thank-you, with respect and affection.

My gratitude also goes to bioengineers Prof Dario Farina and Prof Deborah Falla (University of Goettingen, Germany) and Dr Andrea Merlo (Polytechnic of Turin, Italy) for the creation of the data analysis software without which a reliable research project into mastication would never have been possible.

Many thanks to Prof Guglielmo Ramieri and Dr Francesca Bianchi (University of Turin, Italy) for the special collaboration in the maxillo-facial research studies.

Thank you also to Prof Placido Bramanti (University of Messina, Italy) for his availability with the magnetic resonance imaging and to Prof Giuseppina Cutroneo (University of Messina, Italy) for the valuable morphological evaluation.

I wish to thank Dr Luca Cortina for his availability and great talent that I very much appreciated in the preparation of images and charts, Dr Corrado De Biase for managing the bibliography section, Dr Maria Grazia Incardona for her help in the management of the images of cases, Dr Luigi Sordella for the management of the images, and the valuable staff in the offices of Dr Mario Serra and Dr Luca Bava for their collaboration and for putting up with such a busy orthognathodontist.

My sincere gratitude goes to the staff at Wiley who helped bring this book to completion and who supported me throughout this entire project: Rick Blanchette, Nick Morgan, Catriona Cooper, Teri Jensen, and Jennifer Seward; and to the project manager Aileen Castell and the copy editor Peter Lewis.

A special thank you to Victoria Clifford for quick and professional translation services.

Last but not least, thanks to all our undergraduate and postgraduate students of the University of Turin and to the professionals for their enthusiasm and for providing fundamental contributions over time to the acquisition, processing, and recording of data, particularly to Dr Francesca Talpone for her care and the safekeeping of the research materials, especially in the initial, threatened stages of this project.

Maria Grazia Piancino

Chapter 1

Introductory Explanation of Masticatory Function

Contents

Understanding Masticatory Function in Unilateral Crossbites, First Edition. Maria Grazia Piancino and Stephanos Kyrkanides.

1.1 Introduction

Mastication is one of the most important functions of the stomatognathic system. *It is a highly coordinated neuromuscular operation and features rapid mandibular movements* that demand continual modulation and adaptation to load. The nervous system, peripheral receptors (which determine sensory input), and the masticatory muscles (which produce the response from the brain and adaptation of movement) are continually involved during mastication. This is a complex process and *plays a fundamental role in the quality of life for patients during childhood, maturity, and old age*.

Mastication is *a rhythmic and phylogenetically ancient movement*. The best-known players in this process are the teeth; these are no longer a vital organ for humans (as they are for animals, for example), but they are still of fundamental importance both in terms of healthy functioning of the stomatognathic system and for social relationships. In fact, the peripheral input arriving from the periodontal receptors of teeth is numerically concentrated, sensitive, highly specialized, and extremely fast in reaching the neural centers allocated to masticatory control. Experimental studies on the topic have identified the mechanisms in animals during phylogenetic development that maintain and control the chewing cycles, mechanisms that are extremely precise in humans too. However, it is the cerebral cortex – which is so developed in human beings that it takes up half of the brain area – that controls the chewing pattern.

At this point, the "clinical physiopathology of masticatory function" becomes of specific interest, particularly the search to link masticatory function with dental occlusion, structural and neuromuscular structures, and the whole brain (Figure 1.1). This scientific interest emerged and was developed during the 1980s at the School of Orthognathic Studies in the University of Turin under

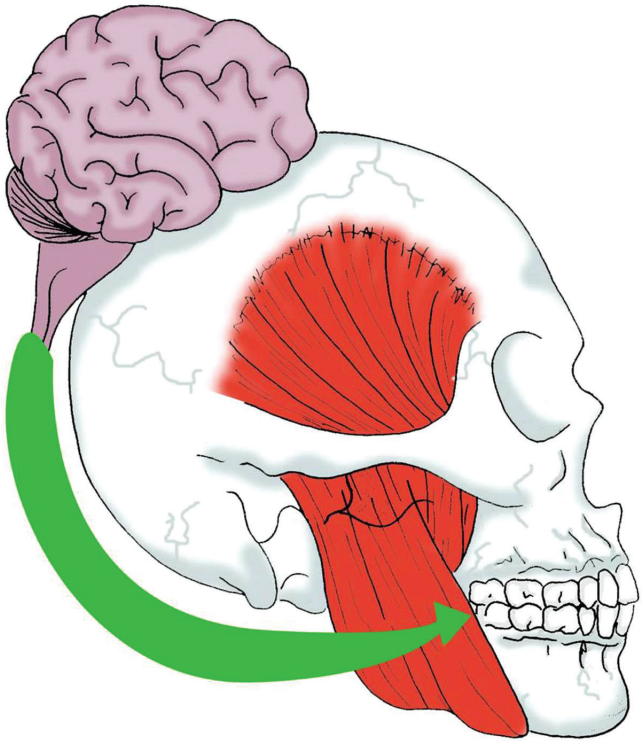


Figure 1.1 Linking masticatory function with dental occlusion, cranial structure, and neuromuscular activity.

the leadership of Professor P. Bracco. From the very outset, he focused on a functional, multidisciplinary, and especially gnathological approach to the diagnosis and therapy of malocclusions. The study and comprehension of masticatory function was supported by this underlying methodology, without which the research carried out would have been limited to the simple publication of statistical results without any true contribution being made to the improvement of diagnostic and therapeutic procedures. Such contribution is, however, the true objective of all research.

In the fields of orthognathics and prosthetics, the study of occlusion is extremely important, particularly as the correlation between "occlusion" (involving the teeth of upper and lower dental arches), function, aesthetics, and social relationships becomes increasingly acknowledged. An understanding of the relationships between dental occlusion and neural control has been improved beyond question by gnathological knowledge of occlusion (Figure 1.2). It was also clear from very early on that, in order to understand and establish a meaningful clinical study, the gnathological base would have to be supported by an understanding of neurology. The concepts of functional occlusion and neuromuscular control are very close to the question of medical treatment of the psychophysical aspect of humans. This concept is clearly expressed in Springer's *International Journal of Stomatology and Occlusion Medicine*, a title created by

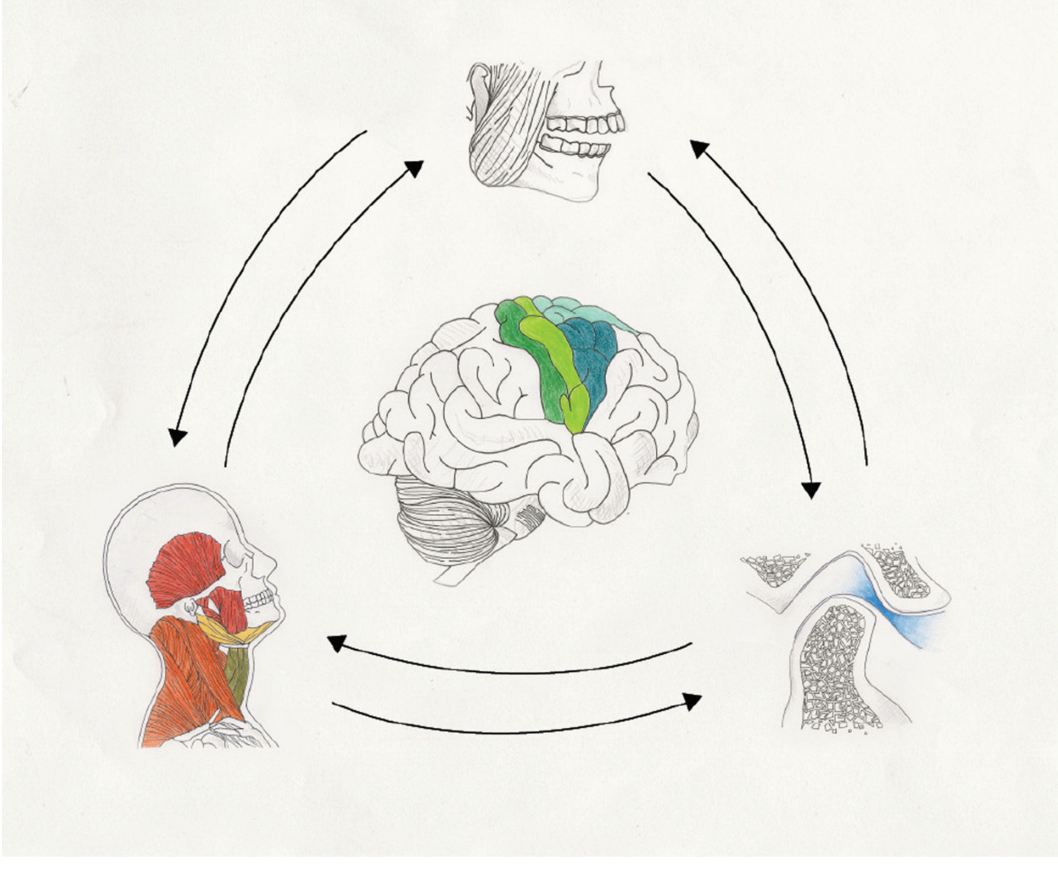


Figure 1.2 The stomatognathic system: relationships between dental occlusion, temporomandibular joint (TMJ) and neuromuscular control. *Source for the muscles:* redrawn from Neff (1999). *Source for the brain:* Purves *et al.* (2000). Reproduced with the permission of Sinauer Associates.

Professor R. Slavicek, one of the most important and dedicated modern-day gnathologists. Dentistry deals with one of the most refined anatomical areas of the body from a neuromuscular point of view – it has an incredible ability to adapt, which, instead of being abused, should be studied and understood in all its physiological aspects in order to allow treatments, "cures" even, that improve its functioning and, consequently, the general psychophysical health of the patient. We hope, then, that the study of mastication can help achieve this objective.

The information gathered from chewing patterns is important in diagnosing the functional condition of the patient; for example, the repetition and variability of mandibular movement, neuromuscular coordination between the two sides, or the ability to adapt to load while chewing a hard bolus. As the brain is entirely engaged during chewing, the importance of this study from a clinical point of view is clear, but the technical, statistical–mathematical, and numeric difficulties have meant that only professionals working specifically in this field have been involved in the research so far. One aspect of evolution is to simplify complex processes, and this is the aim of this book, a first step in this direction. The fine-tuning of functional magnetic resonance imaging (fMRI) has allowed the study of neural control in humans, which we hope will permit us to better understand the functioning of the central nervous system.

The study of masticatory function began at the University of Turin in the 1980s, when the first devices for recording human chewing patterns were produced and sold. The necessary hardware and software were developed and fine-tuned over many years, thanks to the fundamental and collaborative work of the bioengineers Professor D. Farina and Dr A. Merlo. We will later look at the intrinsic difficulties encountered in the study of functional movement from a statistical–mathematical point of view, which were overcome thanks to the skill and effort of these professionals – without their contribution, none of the results later achieved would have been possible. Not only the bioengineers, but also many researchers, professionals, students, and volunteers dedicated their time and energy to this research, even during the period when its clinical significance was still unclear. We believe it important to underline this contribution to clinical research, which requires a true and homogeneous team who all offer hard work and intellectual integrity, albeit in different capacities. These elements, along with a smidgeon of good luck (or, rather, the open-minded approach necessary to identify an important finding amongst millions of others) are essential in achieving scientifically valid and sound results. True research (which presupposes the objective of increasing and developing knowledge) requires skill and passion, as opposed to personal interests connected to obscure indexes of scientific impact. Using research results that have clarified the correlation between masticatory function and occlusion as a starting point, two new directions have emerged thanks to a collaborative partnership between Professor G. Anastasi (University of Messina Italy) and Professor P. Bramanti (IRCCS Centro Neurolesi "Bonino Pulejo," Messina, Italy) – the study in fMRI of neural control during chewing and the histological and biomolecular study of the sarcoglycan–integrin system of the masseter muscle:

1. *The use of fMRI has allowed the study of neural control in human chewing* (Figure 1.3) and represents a step forward in the correlated research not only in dentistry but also, and principally, at a neurological level because it has permitted us to widen our knowledge about the central nervous system via the study of a complex automatism i.e., mastication. Both neural control of mastication and the phenomenon of occlusion differ greatly in their characteristics with regard to human beings as opposed to most species of animals (particularly small laboratory animals). Thus, the study of mastication is now moving beyond the confines of dentistry, the area in which it started, to develop within the field of human neurology and contribute, hopefully, to the understanding of much more serious and debilitating conditions than malocclusion.
2. *The morphological and biomolecular aspects of masticatory muscles are currently a focus of interest*. Despite the fact that considerable information exists, various questions still remain

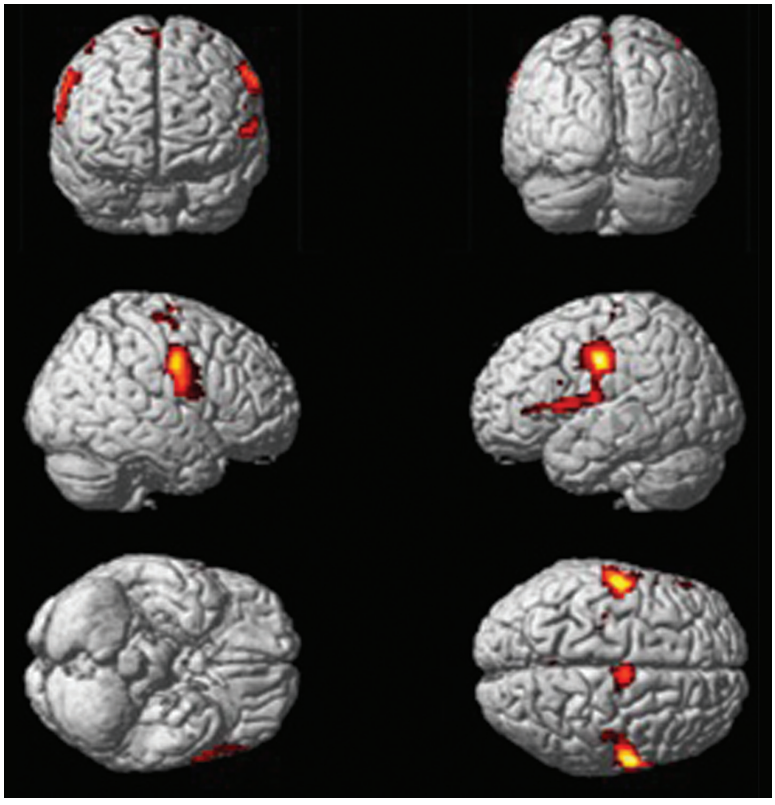


Figure 1.3 Functional magnetic resonance has allowed the study of neural control during masticatory function. *Source:* Bracco *et al.* (2010). Reproduced with the permission of Maney Publishing.

about these muscles that are characterized by special features, both macroscopic and microscopic. However, if the characteristics of a complex muscle like the masseter are to be understood well, it is necessary that there be a strict correlation with the clinical features of masticatory function.

We have outlined these innovative aspects of the study of masticatory function in order to introduce the reader to the topic with an open mind, putting aside preconceptions and convictions that in no way aid true and in-depth understanding of the overall subject.

We wish to underline above all the fact that the stomatognathic system's capacity for "functional compensation" cannot be used as an excuse to justify all and any type of therapy. It is true that *the stomatognathic system possesses remarkable (although restricted) compensatory capacities, but it is also the case that, in general, it has no autocorrection capacity.* This means that, during life, the compensations made will add up and overlap, also with those of poorly selected therapies, to the point where the system is unbalanced and then recovery becomes extremely difficult due to the need for multifactor and multidisciplinary solutions.

The only way to avoid such an imbalance is to prevent it – this is why we must try, *using the appropriate treatment, to restore ideal physiological conditions in each patient* (Figure 1.4). A working knowledge of ideal functioning conditions for each human is important if the right therapeutic cure is to be selected, without adverse side effects that may at times remain hidden, undiagnosed,

Figure 1.4 The beginning of masticatory function.

or impossible to diagnose. The additional peripheral information (on which subliminal information is based) activates an unconscious muscle reaction, at times well balanced but at other times causing unexplained tiredness and/or acute or chronic craniofacial pain. If we also add stress to this list (part of our emotional make-up that often unburdens itself unconsciously onto the stomatognathic system), it is easy to understand how, over time (and as the compensatory actions amass), the system can reach a point of no return. *The chances of correction (as opposed to compensation) during the initial phase are considerable if a correct diagnosis and a correct physiological therapy are made.* But once a phase of compensation is initiated, due to the malocclusion per se or to a traumatic and non physiological therapy the situation is much more difficult, as it becomes multifactor and multidisciplinary, and no feasible solution may remain. Thus, we have to make every effort possible to avoid this phase of imbalance by intervening promptly to correct the occlusal and functional disease with treatments appropriate to physiological and biological conditions. In fact, compensation is evoked to preserve fully functioning order in the best way possible, but at times this may produce collateral damage in the long term. Many discussions, opinions, and arguments have been forwarded on this question, but it is the physiological aspect, not the philosophy of the issue, that interests us. And *the physiology can only be studied, understood, known, and respected*.

The topic is extremely complex and, unfortunately, we do not yet have the right diagnostic means available to fully understand the limits of the stomatognathic system's compensatory function. Therein lies the real aim of this book: *to provide the reader with simple means for a general comprehension (supported by reliable scientific results) of mastication, in order to enable him/her to choose respectful therapies and treatments*. We hope that the book will help professionals in various sectors (including orthodontists, dentists, neurologists, psychiatrists, pediatricians, rehabilitation physicians, physiotherapists, osteopaths, and sports coaches) to understand the causes, development, and consequences of malocclusion in childhood and maturity, in order to adopt and refine therapies that take both physiology and biology into consideration. To achieve this aim from a practical and not simply theoretic point of view, and *to learn how to "think physiologically,"* we need to put aside all our preconceptions and old ways of thinking to make a slight initial effort to study this new subject. Orthognathodontics, just like any other profession, is in continual evolution, and *it is currently of clinical relevance in successful orthodontic or prosthetic treatments to consider not only the repositioning or substitution of teeth within the dental arches, but also, and above all, the effects of treatment on the functional working of the masticatory system*.

1.2 The study of masticatory function

It is now time *to describe briefly the intrinsic difficulties in the study of mastication*, from both technological and clinical points of view, in order to show the reader the evolution, benefits, and limits of the research. Mastication is a complex rhythmic movement that has been refined over millions of years in the animal world and is characterized by precise and reliable neuromuscular

control. Thus, the study of this function is extremely complex and requires not only *advanced technological tools, but also clinical experience and skill*. Furthermore, intellectual integrity is vital, which is why we have published these results only after confirmation at least twice by different groups of researchers treating different patients. Clinical experience, then, is the basis of research planning in order to have a logical plan of action with its roots in physiology – when the research plan is not underpinned by knowledge and experience, there is a danger of producing untrustworthy results. One of the most common defects in the literature is in regard to the nonhomogeneous nature or inaccurate selection of samples where homogeneity is a vital factor. Technological evolution and compliance have also played an important ongoing role.

As a result of the discrepancy between technological resources and clinical comprehension, there was an initial period of confusion that was only resolved with many years of research and effort to gain reliable data. In the 1980s, computers were certainly not so advanced as nowadays, but they could still supply long lists of numbers tracking the movement of the mandible in the three planes. In this initial painstaking phase, all effort was focused on discovering how and in what length of time data could be collected, on the alignment and successive processing of data from different sources, and on the instructions to technicians involved in data collection so that they could record cases reliably. In other words, this period concentrated on resolving solely technical issues, in order to tackle the true question of which and how many of these machine-generated numbers could be used in clinical research. Perfecting the pathognomonic framework was a lengthy and arduous process, closely linked to the technological evolution of hardware and software. In particular, the relevant software was totally rewritten and adapted to the current clinical and technological progress. This took place following an in-depth study alongside bioengineers because it was clear from the start that the study of masticatory function was badly served by the laws of mathematics and statistics. In fact, as chewing patterns are characterized (in physiological conditions) by a balance of repetition and variability, it is difficult to link this study to the mathematical–statistic laws that the international scientific community holds dear. For this reason, much attention was paid to refining a software program that is suitable for the processing of collected data.

The software currently being used in research allows a reliable reading of basic data of chewing patterns and muscular activity, which will be described in Chapters 2 and 3. However, it is necessary to point out that masticatory function cannot be compared with a hemochemical test – to be correctly analyzed, *it needs to be linked to clinical, occlusal, cranial, articular, muscular, and, in some cases, emotive characteristics* of the patient, as previously mentioned. The dentistry profession is obviously interested in the relationships between occlusion (or malocclusion) and chewing patterns. However, as humans are psychophysical beings, the emotive aspect can in some cases become a significant factor, influencing not only the pattern but also the entire motor control of the jaw movement. Thus, it is clear that a multidisciplinary approach to this study is essential, with expertise from various fields being integrated for maximum efficiency.

We will now dedicate a few lines to some key authors in the field who have influenced the work described in this book. Possibly for the reasons outlined above, the research and study of mastication have been awarded little attention, generally by just a handful of international authors. First, we will give a brief description of the significance of early research studies into the topic, looking more closely at those which influenced current understanding of chewing patterns.

J. Ahlgren, 1960–1970: one of the first scholars of chewing patterns in humans. He studied mandibular jaw movement in its entirety, identifying some typical patterns (Ahlgren, 1967).

E. Moller 1960–1970: he carried out an electromyographic (EMG) study of the masseter and temporal muscles of mastication during chewing in order to identify the characteristics of masticatory muscle coordination, a vital factor in understanding neuromuscular control of chewing kinetics (Moller, 1966).

These two authors carried out their studies without the possibility of analyzing mandibular kinetic movement and EMG activity simultaneously. However, despite the limited technology of their age, their results demonstrate high levels of awareness of the issues involved and clinical experience.

Y. Kawamura 1970–1980: the author of *Physiology of Mastication*, a book that joined a few other texts in describing neuromuscular control of chewing patterns based on experimental research of the time (Kawamura, 1974).

C. H. Gibbs and A. Lundeen 1980–1990: these scholars studied chewing patterns using the "case gnathic replicator," an unwieldy device that was difficult to use and required considerable effort but which allowed the collection of data that are still considered accurate and valid today. Moreover, the device succeeded in registering masticatory movement at interincisive, bilateral molar, and bilateral articular levels. These authors described chewing cycles with mathematic precision, making an important contribution to the understanding of masticatory function. Their vital research results are described in Chapter 2 (Lundeen and Gibbs, 1982).

A. Lewin 1985: Lewin focused on the study of mastication in the same period as Gibbs (1989–1990), laying the foundations for diagnostic analysis today. He studied chewing patterns with the "Sirognathograph," a less invasive tool than the case gnathic replicator that also proved easier to use. Thanks to his experience and intuition, Lewin was able to identify the clinical features of chewing patterns, which were then confirmed by further studies and are outlined in Chapter 2 (Lewin, 1985). He is a cornerstone in the field.

J. P. Lund 1970–1990: carried out basic research on the topic and was the first to prove the existence of the central pattern generator (masticatory-like rhythmic bursting in NVsnpr neurons) in the brainstem. This was a vital step in understanding neural control of mastication (Dellow and Lund, 1971; Bernier *et al.*, 2010).

A. Woda 1984: on the basis of research carried out on mastication, he performed an in-depth study into the characteristics of receptors and reflexes of the stomatognathic system, and then outlined their clinical significance (Woda, 1984; Witter *et al.*, 2013). V. F. Ferrario focused on the study of the masticatory muscles coordination during chewing (Ferrario and Sforza, 1996). B. J. Sessle, 1980–1990, studied mastication from an experimental point of view, particularly in non-human primate species (Nakamura and Sessle, 1990). Y. Nakamura 1980–1990: published a book on mastication, gathering together experimental studies referred to in a Tokyo congress in 1990 (Nakamura and Sessle, 1990). K. Takada 1996: developed a system to calculate the masseter muscle's "silent period" during mastication (Takada *et al.*, 1992).

The key research authors that this book makes reference to are C. H. Gibbs and A. Lewin, who conducted their research studies with very different tools from both conceptual and practical points of view (case gnathic replicator and Sirognathograph). They were also very distant geographically, coming from the USA and South Africa, but were active during the same time period (1980–1990). Current research on chewing cycles still today refers to these authors' results and concepts, reconfirming their validity.

1.2.1 The case gnathic replicator

The American researcher Gibbs (1985, USA) developed the first machine designed not only to record human mandibular movement but also to reproduce said movement later. The process involved a heavy, unwieldy, and invasive device, but it had a huge advantage over previous methods in that it allowed the recording and (even more importantly) the reproduction of chewing patterns in plaster models of the dental arches, controlled by six small servomotors for precise and reliable results (Figure 1.5).

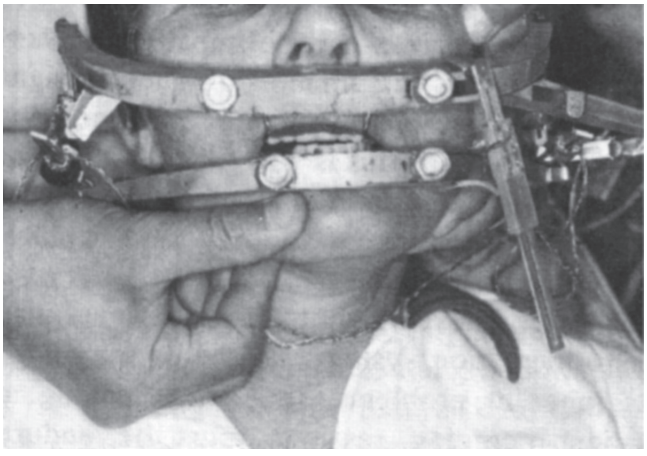


Figure 1.5 Multiple sensor array of Case Gnathic Replicator. *Source:* Lundeen and Gibbs (1982). Reproduced with permission from Elsevier.

Following their research study, Gibbs and Lundeen were able to produce literature on *chewing cycles at the interincisive level and at the molars on the right and left, as well as on bilateral temporomandibular movement*. Their work clarified the process of condylar movement during mastication. At that time, the use of axiographic tracing of TMJ movement was common (opening, closing, protrusion right and left-hand mediotrusion). Great astonishment greeted the discovery that, during mastication, the opening and closing patterns of the condyle on the bolus-loaded side are different to those of the contralateral. This, in fact, meant that at no point in mastication or in any masticatory movement was the position of the condylar axis the point of reference, as it was for all gnathology and dentistry study.

Given the complexity of the device involved, Gibbs's study was carried out on a limited number of patients and, despite the author's intentions, he never managed to make the device feasible for larger-scale studies. However, as already stated, the results obtained are important and still considered valid today (Lundeen and Gibbs, 1982).

1.2.2 The Sirognathograph

At the same time that Gibbs was developing the case gnathic replicator, Lewin (1985, South Africa) was perfecting his Sirognathograph, produced by Siemens (Germany). This was a much simpler piece of equipment to use, but, as a result, was able to produce less data than Gibbs's case gnathic replicator. Lewin's device records *the movement from one point of the mandible*, using a small magnet attached labially between the lower central incisors. The advantage of this method lies in the fact that it is less invasive, both regarding the stomatognathic system in general and the occlusion itself. The weight of the Sirognathograph antenna frame on the head and neck was an initial problem (Figure 1.6) but this problem was later resolved with increasingly advanced technology. It is also easier to use, allowing more cases to be studied (an important factor in developing clinical analysis of chewing patterns). The contribution that Lewin made to clinical analysis and clarity of

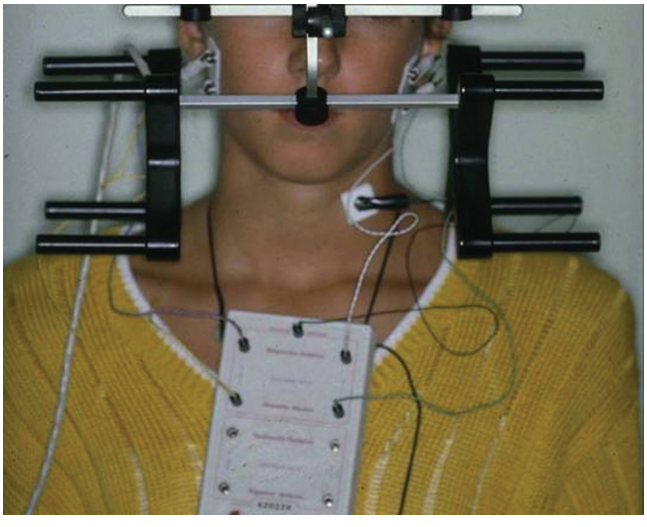


Figure 1.6 Multiple sensor array of the Sirognathograph (Siemens, Germany).

ideas on the protocol for recording chewing function remains fundamental in the research field even today, as his ideas and intuition are continually reconfirmed with more refined tools (Lewin, 1985). The research reported in this book is based on his teaching and guidelines.

1.3 The evolution of electrognathography and electromyography

While case histories, objective clinical examinations, experience, and diagnostic skill of doctors and dentists are essential elements in both professions, the use of advanced technological equipment permits the collection of clinical data that would not otherwise be possible. In particular, for mastication, although it is initially difficult to acquire this data and even more difficult to analyze it, great effort has been put into the development of hardware and software even when many researchers still openly criticized the use of diagnostic tools, claiming that clinical tests were more than sufficient for a correct diagnosis. We now know this is not true – whilst in no way diminishing the importance of clinical tests, the very fact of knowing the characteristics and correct or incorrect functioning of mastication, as well as being able to check post-treatment alteration, is important in the choice of corrective treatment from anatomic and mechanistic points of view and for the restoration of masticatory function in both evolutionary and growth phases. Here, we will outline *the evolution of electrognathography* to explain how the recording of such a process, *whilst seeming relatively simple, in fact required a lengthy and careful process to develop a valid and reliable tool that is also practical and easy to use*. This objective was reached along with the clinical analysis of results that, for some types of malocclusion, is today finally clear and scientifically demonstrated.

1.3.1 Plotted masticatory cycles

This book is based on research results that were initially gathered with the use of the Sirognathograph, developed by A. Lewin and produced and sold in the 1980s by the German company Siemens (Figures 1.7 and 1.8). This device recorded the movements of a magnet which was inserted labially in the lower midpoint of central incisors, and used an antenna frame with multiple sensors to track the motion of the magnet. At first, the Sirognathograph was not connected to a computer or EMG equipment. Connected to a plotter, it reproduced the mandibular movement of single chewing cycles in the three planes (frontal, sagittal, and transverse), but it

Figure 1.7 Magnet of the Sirognathograph.

Figure 1.8 Sirognathograph.

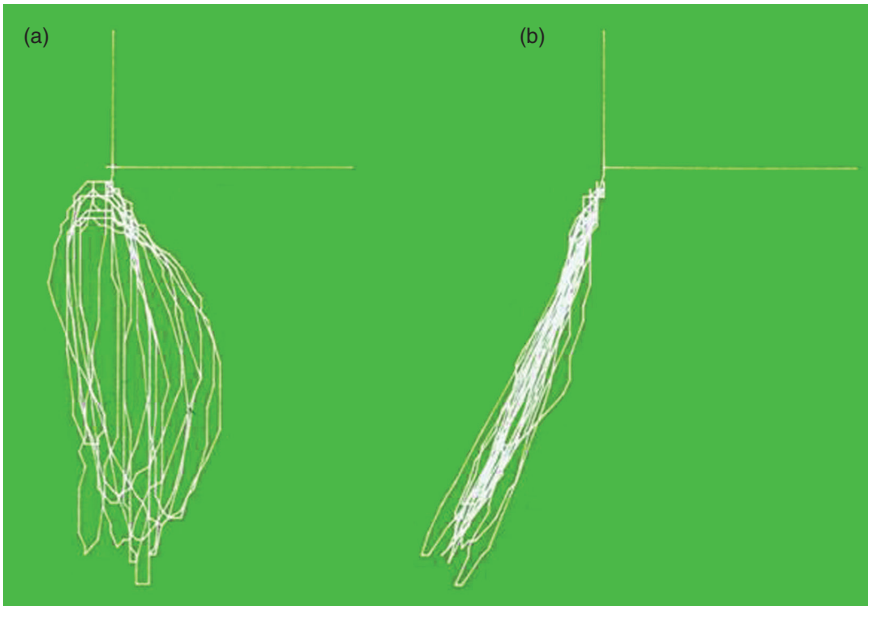


Figure 1.9 Single chewing cycles superimposed, in the frontal (a) and sagittal (b) planes recorded with Sirognathograph and reproduced with a plotter.

was impossible to process or archive any of the collected data (Figures 1.9 and 1.10). Plotting took around 30 min and demanded the constant presence of a technician to change the sheets. Furthermore, it was not possible to gain any information on masticatory muscle activity as the gathering of kinematic and EMG data was still problematic from a technological point of view; thus, in that period, the two processes (study of muscle activity and kinematic recording of mandibular movement) were carried out independently of one another. *The need for computerized*