Introduction

Abstract

"Masticationpedia" explores shifts in scientific understanding within medicine and dentistry through Thomas Kuhn's paradigm shift theory, advocating for interdisciplinary approaches. It highlights a crisis in dental paradigms, particularly in treating masticatory disorders. Traditional models, focusing narrowly on symptoms and mechanical corrections, are deemed insufficient. The document suggests adopting a new paradigm integrating insights from various disciplines for a holistic understanding of masticatory functions.

Clinical case studies illustrate the limitations of conventional orthodontic paradigms, emphasizing the need for a model considering the entire masticatory system's health. A significant portion is dedicated to interdisciplinary research, introducing "metacognitive scaffolds" to enhance communication across disciplines. This ties to a broader epistemological discussion on how scientific knowledge is acquired and applied, questioning statistical measures' reliability and suggesting robust methods.

The document discusses the theoretical implications of adopting a new paradigm in dentistry, embracing masticatory system complexity. Such a shift would enhance diagnostic accuracy and align dentistry with contemporary medical advances, particularly systems biology and holistic care.

Masticationpedia calls for the dental community to explore new paradigms, integrating with other science fields and embracing innovations. It advocates for educational reforms to incorporate these paradigms into dental training.

Looking ahead, the document outlines research areas to support a new dental paradigm, calling for studies examining dental health and systemic condition links, developing new diagnostic tools, and creating integrative treatment modalities.

Practically, it suggests that embracing a new paradigm could alter clinical practice, leading to more personalized treatments and improved patient outcomes. The text highlights the need for changes in dental education, training in new technologies, and socio-psychological aspects of care. Finally, it underscores the importance of collaboration between dentists, researchers, and clinicians.

In summary, Masticationpedia presents a compelling case for a paradigmatic revolution in dentistry, rooted in scientific evolution and interdisciplinary research. It challenges existing practices and proposes a forward-looking approach embracing complexity and holistic care.

Article by **Gianni Frisardi**

Ab ovo[1]

Before diving into the analysis of Masticationpedia, it is necessary to introduce some preliminary considerations. These concern, in particular, two fundamental dimensions - social, scientific, and clinical - that are characteristic of both the current era and the one immediately preceding it.

The phases of paradigm change according to Thomas Kuhn

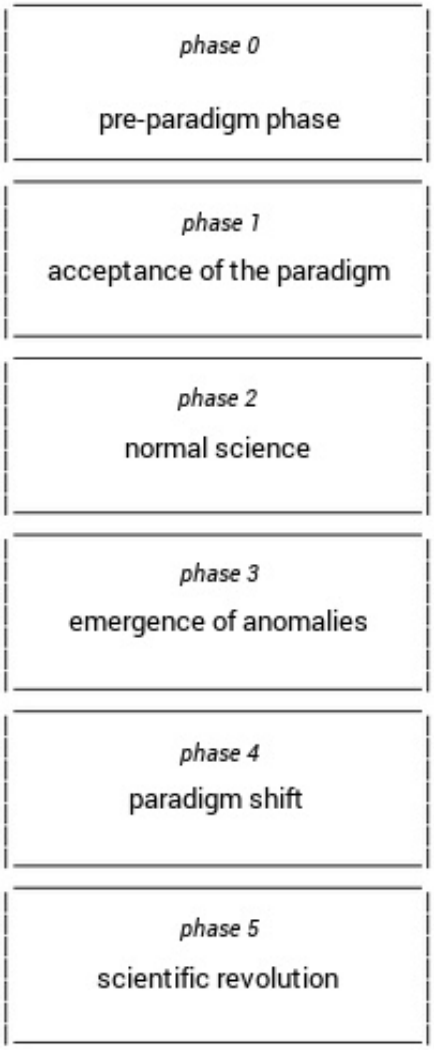
In the course of the last century, there has been an exponential increase in technological and methodological "Innovations",[2] especially in the field of dentistry. These advancements have significantly influenced decision-making strategies, opinions, schools of thought, and axioms, aiming explicitly at improving the quality of life, as highlighted in the "Science of Exposure in the 21st Century".[3] However, this exponential growth implicitly hides conceptual ambiguities - or, in practical terms, "side effects" - which, although sometimes underestimated, have the power to challenge some scientific certainties, making them less rigid and more subject to probability.[4] The sensitive aspects of the current social, scientific, and clinical reality, which may seem contrasting, will be revealed to be complementary by the end of this reading; this is the "Progress of science" according to Kuhn's interpretation and "Epistemology".

In analyzing the progress of science, Thomas Kuhn, in his most famous work, argues that science develops through distinct cycles, reflecting its operational dynamics.[5][6] Kuhn advances the idea that science is structured around paradigms and establishes a clear demarcation between science and pseudoscience, based on the presence of a shared paradigm. For him, the evolution of scientific progress is seen as a continuous curve, yet interrupted by discontinuities represented by paradigm shifts.

Taking on the role of a skilled problem solver, the scientist is engaged in resolving these anomalies. These moments of discontinuity, or scientific revolutions, occur when the existing paradigm can no longer adequately interpret new anomalies, thereby pushing the scientific community towards the exploration and eventual adoption of new paradigms that better align with emerging observations.

Kuhn's phases in Dentistry

Thomas Kuhn identifies in the evolution of a scientific paradigm five distinct phases, a process that holds crucial importance for Masticationpedia. To stay in line with the project's objectives, we will focus on the description of the three most significant phases, as outlined in the book's index.



The phases of paradigm change according to Thomas Kuhn

Thomas Kuhn in his most famous work states that *science cyclically passes through some phases indicative of its operation*. According to Kuhn, *science is paradigmatic*, and the demarcation between science and pseudoscience can be traced back to the existence of a **paradigm**. The evolution of scientific progress is assimilated to *a continuous curve which undergoes discontinuity in paradigm changes*.

Kuhn's phases in Dentistry

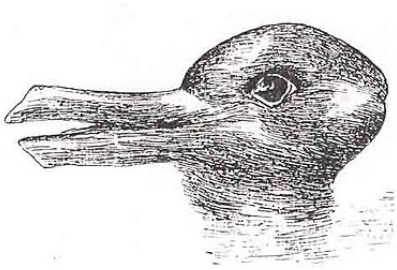
Kuhn, on the other hand, divides the evolution of a paradigm into five phases; this is a fundamental process for Masticationpedia, but to stay tuned with the project we will limit ourselves to describing the three most significant phases shared in the project and indicated in the index of the book:

- ***Phase 2***, or the Normal Science
  For instance, in the second phase of Kuhn's paradigms, called "Normal Science," scientists are considered problem solvers engaged in strengthening the correspondence between the paradigm and natural reality. This phase is based on a set of fundamental principles established by the paradigm itself, which are not subject to dispute but are instead used to define the guidelines for future research projects. During this phase, the development of the necessary measurement tools to conduct experiments takes place, and the majority of the scientific literature is produced. The results obtained in this phase contribute significantly to the advancement of scientific knowledge. In normal science, both successes and failures occur; the latter are identified by Kuhn as "anomalies," i.e., events that contradict the prevailing paradigm.
- ***Phase 4***, or the **Crisis of the Paradigm**
  In response to the crisis, there will be the formation of several new paradigms during this period. These emerging paradigms, therefore, will not originate from the successes of the previous theory, but rather from the rejection of the established models of the dominant paradigm. Continuing along this line, Masticationpedia will dedicate attention to the crisis of the masticatory rehabilitative paradigm, through the review of theories, theorems, axioms, currents of thought, and diagnostic research criteria. Subsequently, the focus will shift to the fifth phase.
- ***Phase 5***, or the **Scientific Revolution**
  Phase 5 is characterized by the scientific revolution. During the period of extraordinary scientific activities, a debate will develop within the scientific community on which new paradigm to adopt. However, the prevailing paradigm will not necessarily be the "truest" or most efficient one, but rather the one that manages to arouse the interest of a sufficient number of scientists and earn the trust of the community. According to Kuhn, competing paradigms have nothing in common, not even the foundations, making them "incommensurable." The choice of paradigm, as mentioned, occurs on socio-psychological or biological bases, with younger scientists replacing the older ones. This battle between paradigms will resolve the crisis, the new paradigm will be named, and science will return to Phase 1. Following the same principle of Phase 4, Masticationpedia will introduce, in the chapter named "Extraordinary Sciences," a new paradigmatic model in the field of Masticatory System rehabilitation, examining its principles, motivations, scientific clinical experiences, and particularly, a radical change in the field of medical diagnostics. This change is fundamentally based on "System Inference," rather than symptom-based inference, assigning primary importance to the objectivity of data.

It's almost taken for granted that Kuhn's scientific philosophy gives priority to discipline, since an anomaly within the genetic paradigm will be more easily recognized by a geneticist rather than a neurophysiologist. This concept, however, seems to contradict the epistemological evolution of Science, thereby making a detailed analysis of this apparent discrepancy appropriate.

Epistemology

The black swan symbolizes one of the historical problems of epistemology: if all the swans we have seen so far are white, can we decide that all the swans are white?
Really?



Kuhn used optical illusion to demonstrate how a paradigm shift can cause a person to see the same information in a completely different way: which animal is the one here aside?
Sure?

Epistemology (from the Greek ἐπιστήμη, epistēmē, meaning "certain knowledge" or "science", and λόγος, logos, "discourse") represents that branch of philosophy dedicated to the study of the necessary conditions for acquiring scientific knowledge and the methods through which such knowledge can be achieved.[7] This term specifically refers to that section of gnoseology that investigates the foundations, the validity, and the limits of scientific knowledge. In English-speaking countries, the concept of epistemology is commonly employed almost as a synonym for gnoseology or theory of knowledge, that is, the discipline that examines the study of knowledge in general.

It is important to emphasize that the central problem of epistemology, today as in the times of Hume, is the issue of verifiability.[8][9]

The Hempel's paradox asserts that the observation of every white swan provides support to the statement that all ravens are black;[10] in other words, every example that does not contradict the theory confirms a part of it. According to this paradox:

$$A \Rightarrow B = \neg A \vee B$$

According to the criterion of falsifiability, no theory can be considered definitively true, as although there is only a finite number of experiments that can confirm it, theoretically there is an infinite number of experiments that could refute it.[11]

But it's not all so obvious...

...because the very concept of epistemology meets continuous implementations, like in medicine:

- $P-value$: In medicine, for example, to confirm an experiment or validate a series of data collected through laboratory instruments or surveys, reliance is placed on "Statistical Inference," and in particular on a well-known value called "significance test" (P-value). However, even this concept, now rooted in the practice of researchers, is being questioned. A recent study has focused attention on a campaign conducted in the journal "Nature" against the use of the "significance test."[12] With over 800 signatories, including eminent scientists, this campaign can be seen as an important turning point and a "Silent Revolution" in the field of statistics, touching logical and epistemological aspects.[13][14][15] The critique is aimed at overly simplified statistical analyses, still present in numerous publications. This has stimulated a debate, sponsored by the American Statistical Association, which led to the creation of a special issue of "The American Statistician Association" titled "Statistical Inference in the 21st Century: A World Beyond p < 0.05", containing 43 articles by statisticians looking towards the future[16]. This special issue proposes new ways to communicate the significance of research findings beyond the arbitrary threshold of a P-value and offers guidelines for research that accepts uncertainty, is reflective, open, and modest in claims.[16] The future will reveal whether these attempts to provide more solid statistical support to science, beyond traditional significance tests, will find resonance in future publications.[17] This evolution aligns with Kuhn's concept of scientific progress, reflecting a reworking of some descriptive statistical content within the discipline.
- **Interdisciplinarity**:
  In the field of science policy, it is universally recognized that solving science-based problems requires an interdisciplinary research approach (IDR), as highlighted by the European Union's Horizon 2020 project.[18] Recent studies have explored the reasons for the cognitive and epistemic difficulties that researchers encounter in conducting IDR. One identified cause is the decline of philosophical interest towards the epistemology of IDR, attributed to the dominant "Physical Paradigm of Science." This paradigm limits the recognition of significant developments in IDR, both in the context of the philosophy of science and in the practice of research itself. In response, an alternative philosophical paradigm has been proposed, called the "Engineering Paradigm of Science," which offers alternative philosophical perspectives on fundamental aspects such as the purpose of science, the nature of knowledge, the epistemic and pragmatic criteria for the acceptance of knowledge, and the role of technological tools. Consequently, it highlights the need for researchers to make use of metacognitive support structures, called metacognitive scaffolds, to facilitate the analysis and reconstruction of the processes by which knowledge is constructed across different disciplines. In the context of IDR, such metacognitive scaffolds are essential for promoting effective communication between disciplines, allowing scholars to analyze and articulate how each discipline contributes to the construction of knowledge.[19][20]

Interdisciplinarity

A superficial view might suggest that the epistemic evolution of science is marked by an apparent opposition between the aspects of disciplinarity, highlighted by the "Physics Paradigm of Science" (which sheds light on anomalies), and those of interdisciplinarity, represented by the "Engineering Paradigm of Science" (and the related concept of metacognitive scaffold). However, as will be explored in this chapter, these two perspectives are not actually in conflict; on the contrary, they prove to be complementary, as both contribute to the generation of a "Paradigmatic Innovation" without any form of conflict.

It could then be argued that "Innovations" themselves represent "Progresses of Science," as illustrated in the article "Scientific Bases of Dentistry" by Yegane Guven. This work explores the impact of biological and digital revolutions on education and daily clinical practice in dentistry, covering topics such as personalized regenerative dentistry, nanotechnologies, virtual reality simulations, genomic information, and stem cell research.[21] Although the innovations mentioned are technological and methodological in nature, it is crucial to recognize that true scientific progress does not occur exclusively through "Incremental Innovations" or "Radical Innovations," but is fundamentally achieved through "Paradigmatic Innovations."

In the strictest sense of the term, "Paradigmatic Innovations" are a change in thinking and awareness that spreads throughout all of humanity, affecting different social layers, from the Copernican revolution to the recent trend of approaching biological

phenomena with a stochastic method.[22]

This epistemological context, which includes initiatives such as the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD), Evidence-Based Medicine, and others, is further explored in the Masticationpedia project. The latter aims to highlight the dynamics and dialectics of progress in the science of masticatory rehabilitations, emphasizing the anomalies that stimulate a change in thought and, consequently, a "Paradigmatic Innovation."

Before proceeding, it might be appropriate to observe a very concrete and significant case.

Dental Malocclusion

"Malocclusion" derives from the Latin "malum," meaning "bad" or "wrong," and literally refers to an improper closure of the teeth.[23] The notion of "closure" may seem intuitive; however, the adjective "bad" requires careful consideration, as its application in the medical context is less obvious than it may appear.

To approach an understanding of the term, this introduction poses a seemingly simple yet profoundly complex question, which in turn raises a series of related inquiries in the field of masticatory rehabilitation and, more specifically, in orthodontic disciplines: what exactly is meant by "Malocclusion"? It's interesting to note that, in 2019, a search for the term "Malocclusion" on PubMed yielded a whopping 33,309 articles,[24] indicating a lack of uniform terminological consensus on the subject. Among these articles, some may provide conclusions of significant relevance, as strikingly demonstrated by the work of Smaglyuk and colleagues. This particularly significant study explores the interdisciplinary approach in diagnosing malocclusions:[25]

> *«Diagnosis, treatment strategies, and prevention of anomalies and dento-facial deformities should be approached by considering the organism as a whole, especially in children, where the physical structure is still in the formative stage. It is essential to recognize the interconnectedness between the form and function of various organs and systems of the body, as these relationships are crucial for devising an effective treatment plan that respects and promotes the harmonious development of the patient.»*

Another noteworthy piece of data emerged when, also in 2019, PubMed was specifically queried for interdisciplinary approaches in diagnosing malocclusions: the results drastically decreased to only four articles.[26]

This observation regarding the topic of "Malocclusion" underscores two critical points: firstly, it highlights a growing awareness of anomalies that could trigger phase 4 of Kuhn's model, suggesting a potential moment of paradigmatic shift. Secondly, it signals a bifurcation in epistemic choices regarding the topic: on one hand, the tendency to generate Incremental Innovations, as evidenced by the other 33,309 articles, and on the other hand, a propensity towards a new gnoseological trajectory that favors a "Paradigmatic Innovation".

To explore the concept of "Paradigmatic Innovation", considered essential in this context, let's begin by posing a specific question:

Another noteworthy piece of data is that if in the same year, 2019, PubMed was queried about the interdisciplinarity in diagnosing malocclusions, the result dropped drastically to only four articles.

These premises regarding the question of "Malocclusion" indicate, on one hand, an alertness to anomalies that tend to trigger phase 4 of Kuhn and, on the other hand, a bifurcation in epistemic choice on the topic: one that generates Incremental Innovations (other 33,309 articles, perhaps) and another that prefers a new gnoseological path of "Paradigmatic Innovation".

Let's try to approach part of the concept that considers "Paradigmatic Innovation" essential, asking, for example:

Figure 1a:
Patient with malocclusion, open bite and right posterior crossbite who in rehabilitation terms should be treated with orthodontic therapy and/or orthognathic surgery.

What does "Malocclusion" mean?

To answer the previously posed question, let's examine a clinical case that clearly exemplifies "malocclusion".

The case involves a patient presenting a type of occlusion commonly defined by orthodontists as "malocclusion", characterized by a unilateral posterior crossbite and an anterior open bite;[27] these conditions represent a form of malocclusion that can be effectively treated through the use of fixed orthodontic appliances, sometimes in combination with orthognathic surgery if necessary.[28] The crossbite is identified as a significant alteration from normal occlusion, which requires concurrent treatment with the open bite due to their functional interrelationship.[29][30][31]

It becomes clear that a deterministic approach to diagnosing such obvious occlusal incongruence might lead to considering both the crossbite and the open bite as both causes and effects of malocclusion, consequently suggesting orthodontic intervention to restore "Normocclusion". This mode of thinking would presuppose that the model (the masticatory system) should be "normalized" with respect to occlusion. Interpreted conversely, this would imply that the occlusal discrepancy is the cause of malocclusion and, by extension, pathology of the Masticatory Apparatus. (Figure 1a).

In the context of a clinical case highlighting the presence of malocclusion, with particular attention to the unilateral posterior crossbite and anterior open bite, the importance of dialogue between dentist and patient emerges. This informative

conversation is crucial not only for sharing the diagnosis and treatment options but also for understanding the patient's concerns, expectations, and desires. Here's how such a dialogue might unfold:

Dentist: "Considering your malocclusion situation, which includes an open bite and unilateral posterior crossbite, treatment is recommended to improve both aesthetics and chewing functionality. Without intervention, you may experience future problems such as bruxism, swallowing difficulties, and potential postural issues."

Patient: "Absolutely not, doctor. I have no intention of undergoing any treatment. I may have an imperfect smile, but my chewing function is excellent. I eat without any issues, so I don't see why I should worry."

Dentist: "I understand that you feel comfortable with your current chewing condition. However, it's important to consider that some problems may not be immediately evident but could manifest over time, affecting not only oral health but also overall well-being."

Patient: "I appreciate your concern, doctor, but really, I have no problems chewing or swallowing. And as for bruxism or postural issues, I don't suffer from them. I'm also very physically active. For me, undergoing treatment that I don't feel is necessary would be excessive."

Dentist: "I understand your position. It's crucial that you feel comfortable with any decision made regarding your health. My role is to inform you about potential long-term implications and available treatment options. If you ever change your mind or need further information, know that I'm here to assist you."

The situation becomes particularly critical when we consider the patient's verbal language regarding their chewing functionality. This can be misleading, as it may not reflect a detailed understanding of the pathophysiology of the occlusal state. On the contrary, it could paradoxically indicate an intact system if interpreted through a "machine language" converted into verbal terms. In this impasse, neither the patient nor the observer (dentist) can assert with certainty the presence of an actual "Malocclusion."

In this context, the reference to the American Statistical Association's critique entitled "Statistical inference in the 21st century: A World Beyond $p < 0.05$" becomes relevant, as it invites the researcher to navigate uncertainty with sensitivity, reflexivity, openness, and modesty in assertions.[16] This stance paves the way for interdisciplinarity as a key to addressing such complex issues.

The interdisciplinary approach becomes crucial in interpreting the biological phenomenon of "Malocclusion" through a stochastic mindset, which will be explored in more detail later.

A stochastic observer might note that, at time T_n, there is a low probability that the patient is in a state of occlusal disease, given their expression of optimal psychophysical well-being. This leads to the conclusion that occlusal discrepancy does not necessarily entail a neuromuscular and psychophysical functional disorder. Therefore, the masticatory system should not be normalized solely to occlusion but requires a broader understanding that includes the Trigeminal Nervous System.

To assess the integrity of the patient's Trigeminal Nervous System in the presence of "malocclusion," specific electrophysiological tests were performed. The results of these tests, shown in Figures 1b, 1c, and 1d (with explanations in the captions), should be interpreted as a "Conceptual Rationale" within the context of the "Malocclusion" issue. These introductory data reveal an apparent discrepancy between the occlusal state, which traditionally might be considered pathological, and the neurophysiological data demonstrating perfect synchronization and symmetry of trigeminal reflexes.

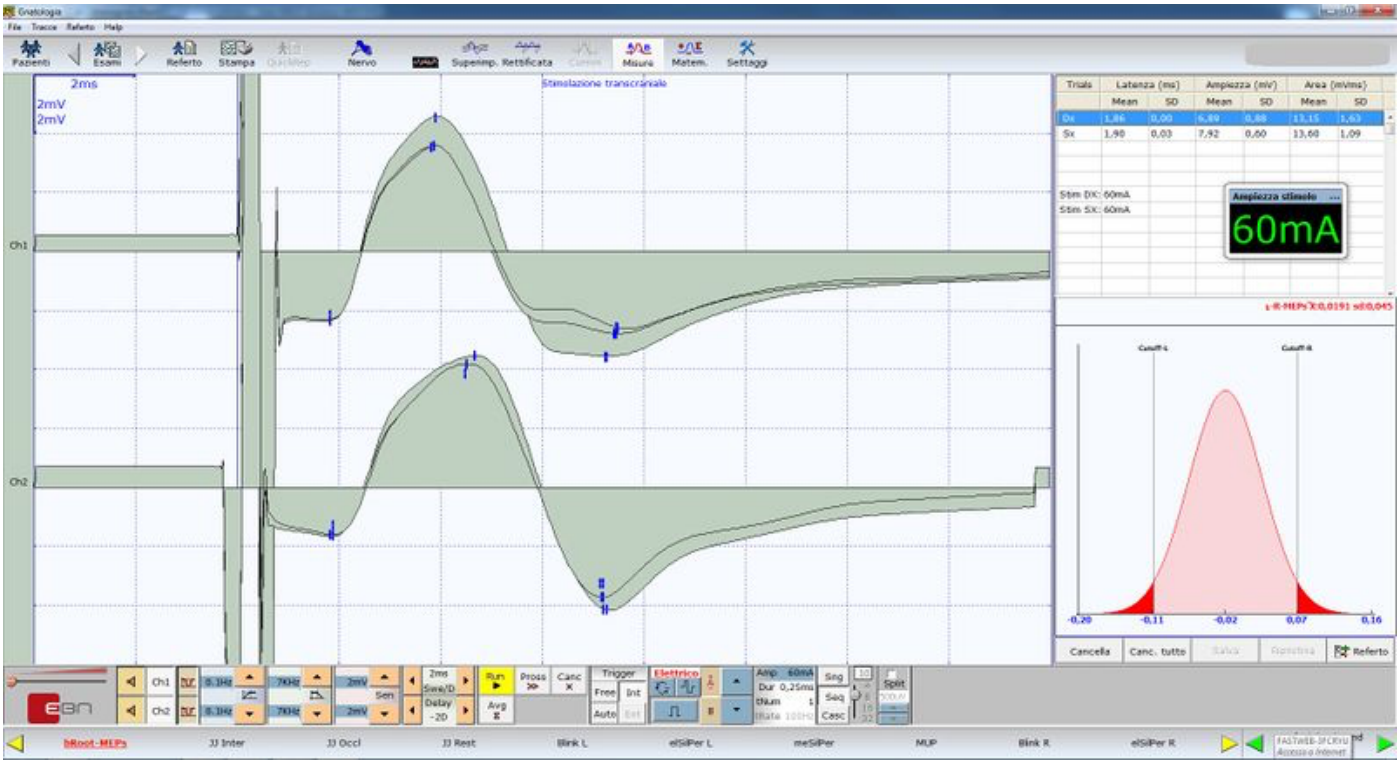


Figure 1b: Figure 1b displays the results of a motor-evoked potential test obtained through transcranial electrical stimulation of the trigeminal nerve roots. The focus is on structural symmetry, which was calculated by comparing the peak-to-peak amplitude of the evoked potentials in the right masseter muscle (upper trace) and left masseter muscle (lower trace).

Through the examination of these electrophysiological data – Figures 1b, 1c, and now 1d – a picture emerges that challenges conventional interpretations of malocclusion and its clinical implications. The observed functional symmetry in these measurements indicates that the approach to diagnosing and treating malocclusions could significantly benefit from a broader evaluation, including detailed analysis of neuromuscular function. These results emphasize the importance of an interdisciplinary and integrated diagnostic and therapeutic model that goes beyond simply correcting occlusal discrepancies to include an overall assessment of the well-being of the masticatory system and, by extension, the patient.

> *Occlusal Dismorphisms and Not Malocclusion .....which, as we will see shortly, is an entirely different matter.*

Conclusion

Before proceeding with any conclusion, it is crucial to clarify some fundamental concepts that will be explored in more detail in specific chapters of Masticationpedia.

The masticatory system should be interpreted as a "Complex System"[32] rather than being reduced to a simple

biomechanical mechanism focused solely on dental occlusion. From this perspective, occlusion represents only one of the numerous subsets operating within a broader context. These subsets include periodontal receptors, neuromuscular spindles, motor unit recruitment, the central nervous system, and the temporomandibular joint. The interaction among these components gives rise to what we can define as "Emergent Behavior", specifically masticatory behavior.

This notion implies that the emergent behavior of the system cannot be interpreted or predicted solely based on objective data extracted from a single subset. Instead, it is necessary to assess the integrity of the system as a whole before proceeding with an analytical segmentation for a detailed description. There are significant intellectual and scientific movements addressing this challenge. A notable example is found in the work of Kazem Sadegh-Zadeh, "Handbook of Analytic Philosophy of Medicine".[33]

In light of these considerations, the discussion on the case at hand follows the following linguistic logic: the various subsets of the masticatory system, such as teeth, occlusion, temporomandibular joints, and muscles, exhibit "Coherence" with the Central Trigeminal Nervous System (as illustrated in Figures 1b, 1c, and 1d). Consequently, the use of the term "Malocclusion" is inadequate; it would be more appropriate to speak of "Occlusal Dysmorphisms".

> *«The proposition to consider the masticatory system as a "Complex System" does not imply the denial of existing rehabilitative therapies, such as prosthetic, orthodontic, and orthognathic treatments aimed at correcting masticatory dysfunctions. On the contrary, this innovative approach aims to reintegrate and enrich medical knowledge in rehabilitative dental disciplines, providing an alternative perspective to the scientific reductionism that tends to interpret biological phenomena in an overly deterministic manner.»*

Adopting a perspective that transcends the boundaries of individual specializations, as highlighted by the importance of interdisciplinarity, is crucial for enriching diagnostic and therapeutic models in dentistry. This approach is exemplified in the clinical case of a patient treated with the OrthoNeuroGnathodontic methodology, which provides an integrated overview of the masticatory system, combining aesthetic and functional-neurophysiological aspects. This interdisciplinary model aims to achieve "Occlusal Stability" and prevent "Relapses," particularly relevant in orthodontic and orthognathic treatments.[34][35] This perspective does not aim to eliminate existing rehabilitative practices but, on the contrary, seeks to enrich and restore value to dental rehabilitative disciplines, while offering an alternative to the reductionistic view that often dominates the interpretation of biological phenomena. In this context, an "Extraordinary Science" is introduced, which leverages interdisciplinarity to expand the boundaries of medical knowledge and practice. In the meantime, let us take a reflective pause thanks to a provocative question from our curious companion, Linus Sapiens, the yellow figure positioned on the left. This allegorical interaction invites us to consider the complexity of the masticatory system with a sense of wonder and curiosity, emphasizing the importance of remaining open to new perspectives and innovative solutions in the field of dentistry.

What do we mean by "Complex Systems" when we are talking about masticatory functions?

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