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An Investigation into the management of awake bruxism: A Systematic Literature Review

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A thesis submitted to fulfil requirements for the degree of Master of Philosophy

ORIGINALITY STATEMENT

This is to certify that to the best of my knowledge, the content of this thesis is my own work. This thesis has not been submitted for any degree or other purposes.

I certify that the intellectual content of this thesis is the product of my own work and that all the assistance received in preparing this thesis and sources have been acknowledged.

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ABBREVIATIONS

AB	Awake Bruxism
BCE	Before Common Era
BDJ	British Dental Journal
BF	Biofeedback
BoNT	Botulinum Toxin
bvFTD	bi-Frontotemporal Dementia
BTX	Botulinum Toxin
CBT	Cognitive Behaviour Therapy
CMD	Craniomandibular Dysfunction
eCBT	email based Cognitive Behaviour Therapy
sCBT	sticky note based Cognitive Behaviour Therapy
EMA	Ecological Momentary Assessment
EMG	Electromyography
FL-A	First Line non-invasive Approach
GML	Guided Music Listening
GPT-9	Glossary of Prosthodontic Terms 9th edition
HP	High Parafunctional
ICSD-3	International Classification of Sleep Disorders 3rd edition
JADA	Journal of the American Dental Association
LP	Low Parafunctional
MDD	Major Depressive Disorder
MFP	Myofascial Pain
MPD	Myofascial Pain Disorder
mTMD	Temporomandibular Disorder myalgia
MVC	Maximum Voluntary Contraction
nFTC	non-Functional Tooth Contact
NSAID	Non-steroidal Anti-Inflammatory Drug
OBC	Oral Behaviours Checklist
OFPG-6	Orofacial Pain Guidelines 6th edition

PICO	Participants, Intervention, Comparator, Outcome
PPT	Pain Pressure Thresholds
RCT	Randomised Controlled Trial
SB	Sleep Bruxism
SD	Standard Deviation
SNRI	Serotonin & Norepinephrine Reuptake Inhibitor
SSRI	Selective Serotonin Reuptake Inhibitor
STAB	Standardised Tool for the Assessment of Bruxism
STAI	State-Trait Anxiety Inventory
TMD	Temporomandibular Disorder
VDO	Vertical Dimension of Occlusion

ABSTRACT

Awake Bruxism (AB) covers a number of varied oral activities and behaviours all of which have the potential to be damaging to teeth, oral soft tissues, masticatory muscles and the temporomandibular joint. Even though there is a paucity of studies examining the management of AB, the purpose of this systematic review is to answer the following question: -"For teenage and adult humans (aged 13 and above), how effective is the most frequently evaluated form of management to reduce awake bruxism behaviour compared to other interventions?"

On 30th August 2022 the search strategy was applied to the following databases: - Medline, Embase, Scopus, LILACS,CINAHL, and Trip medical. In addition it was applied to OpenGrey and Google. The results of the search were imported into Covidence and subjected to the following inclusion criteria: Randomised Control Trials (RCTs), non RCTs, reports or trials, case series reports. Exclusion criteria were: - studies, reports or information regarding Sleep Bruxism (SB), studies involving anyone 12 years of age or younger.

From 210 studies reviewed for full text, there are 9 included studies: 3 using biofeedback, 2 using Guided Music Listening (GML) and one each using drug therapy, email reminders, habit-reversal and counselling and self-management.

Of the 3 biofeedback studies, two did not have meaningful conclusions because of either a large

participant drop out, or very short study duration. For the 2 GML studies the authors conceded that the statistically significant improvement was not clinically significant and that it may only be a secondary form of management. The drug study was specifically aimed at patients receiving Selective Serotonin Reuptake Inhibitor (SSRI) therapy for depression who developed secondary bruxism behaviour. Each of the included studies in this literature review only looked at a single type of management technique without comparing with any other mode of management. All these forms of management showed a significant decrease in AB activity, it is not possible to make direct comparison and say one management technique is more effective than the other. Habit-reversal maintained the decreases over 6 month and 12 month follow up. With biofeedback the treatment period lasted 3 weeks, but there is no mention of later follow up. The email reminders ran for 20 days. This study also had a third group who used sticky notes strategically placed around home and place of work. This was the only study with a comparator. The sticky note group achieved better results than the control group but not as good as the email group.

Assessment of quality/risk of bias was done for all the included studies by applying either the Newcastle Ottawa scale or the RoB2 scale dependant on the type of study involved. Results are presented in tables.

In the Counselling and Self-Management study the results were evaluated over 2 months. But in that time the participants were given sufficient awareness and training that they had skills to carry forward. This is the only one of the included studies achieving a good quality/risk of bias rating, is the study with the simplest management technique (i.e. not requiring EMG biofeedback, guided music listening or an email reminder system) and in addition is the study with the most immediate application for general practice.

No funding has been received for this study.

The registered name of the study with PROSPERO is: “An investigation into the management of awake bruxism: a systematic review” and the number is: CRD42022351309.

STRUCTURE OF THESIS

PAGE No.

CHAPTER 1:INTRODUCTION & OVERVIEW

1.1 INTRODUCTION

"I have been watching him for a long time, grinding his teeth and opening and shutting his fists ……he had merely the appearance of calm. He had collapsed like a rotten tree". All quiet on the western front, Ch. 6 – Erich Maria Remarque

The English word bruxism is derived from the ancient Greek βρύκειν (*brúkein*) meaning to clench or grind (gnash) the teeth. For the majority of us who engage in the activity of clenching or grinding teeth the noun is bruxer and the verb is to brux. In the Greek versions of the New Testament the term used was βρυγμὸς των οδόντων (*brygmos ton odonton*) gnashing of teeth. This entered medical Latin terminology as brygmus. Brygmus was defined by Laurenzi in 1664 as "*stridor ex dentibus collisis*" (the noise produced when teeth collide). Until the 20th century, brygmus was the usual term used professionally for teeth grinding, it fell from use as the scientific terms bruxomania and bruxism were introduced (1).

Bruxism is an umbrella term which describes any solo, non-functional oral behaviour; if typically during the day it is known as Awake Bruxism (AB) or whilst asleep Sleep Bruxism (SB). These two manifestations are now considered two separate entities (2), quite possibly linked or related in other ways (3).

This study is focussed on AB.

What does AB involve?

- The most frequent form of AB involves the mandibular elevator muscles (predominantly Masseter and Temporalis) lifting the mandible to eliminate the freeway space (this is the space that is naturally formed between the biting surfaces of the mandibular and the maxillary teeth when the mandible is resting) so bringing the lower teeth into contact with the upper teeth. This contact can vary from light fleeting touching lower teeth against uppers

through varying degrees of intensity up to hard continuous clenching. The mandible may be pushed anteriorly, laterally or combinations of the two and either gently moved back and forth or held in one position. All variations of teeth contact involve repetitive use of the elevator muscles and can cause symptoms and pain (4).

- Some people hold the jaw in tension without the teeth in contact.
- Lip biting, cheek biting, sucking the cheeks against the teeth, thrusting the tongue against the teeth, persistent sucking with the tongue on the palate or teeth.
- Repetitively chewing gum or sweets. (5), (6).

Many other terms have been used in the past: neuralgia traumatica (7), bruxomania (8), occlusal habit neurosis (9), stridor dentium (10), bruxogenic syndrome (11), thegosis (12), (13).
AB used to be considered pathological, frequently referred to as parafunction. Many researchers have attempted to calculate the incidence of it in the population groups that they were studying. Now it is considered a normal human behaviour, one that we all engage in from time to time, but one which at times and perhaps depending on circumstances, we over-indulge, it becomes pathological and causes either pain or teeth damage or both (14). Or as Watanabe and colleagues state very succinctly in their introduction – " *bruxism events increase the likelihood of dental problems"*(15). Because of this it frequently needs to be managed.

1.2 DEFINITION & CLASSIFICATION

"The feelings of kindness and gentleness which I had entertained but a few moments before gave place to hellish rage and gnashing of teeth" Frankenstein, Ch 16 - Mary Shelley

The Oxford English Dictionary defines bruxism as: - "Involuntary or unconscious grinding clenching of the teeth, esp. during sleep" (16). It dates the first published use of the word as in 1932 in the Psychoanalytical Review. The same paper had appeared in Dental Cosmos in 1931 written by Dr. Bertrand S. Frohman an M.D. and psychotherapist (17).
In the ninth edition of the Glossary of Prosthodontic Terms (GPT-9) bruxism is defined as "1. the parafunctional grinding of teeth; 2. an oral habit consisting of involuntary rhythmic or spasmodic non-functional gnashing, grinding, or clenching of teeth, in other than chewing movements of the

mandible, which may lead to occlusal trauma" (18).

In the third edition of the International Classification of Sleep Disorders (ICSD-3) published by the American Academy of Sleep Medicine, the definition is: "Bruxism is a repetitive jaw-muscle activity characterized by clenching or grinding of the teeth and/or by bracing or thrusting of the mandible (19).

In the 6th edition of the Orofacial Pain Guidelines (OFPG-6) (20) bruxism is defined as "a repetitive jaw-muscle activity characterised by clenching or grinding of the teeth and/or by bracing or thrusting of the mandible; can occur during sleep (sleep bruxism) or during wakefulness (awake bruxism).

In the last 8 to 10 years the topics of definition and classification have provoked extensive debate in the literature. In 2013 a worldwide group of bruxism researchers published a consensus paper (21). It was the most cited paper in that journal of that year and to date Web of Science indicates 661 (September 2023) citations in all. In it the authors quoted the most common definitions in use from GPT-9, ICSD-3 and OFPG-6. Having critically examined them, they proposed a new, simpler definition: -

"Bruxism is a repetitive jaw-muscle activity characterized by clenching or grinding of the teeth and/or by bracing or thrusting of the mandible. Bruxism has two distinct circadian manifestations: it can occur during sleep (indicated as sleep bruxism) or during wakefulness (indicated as awake bruxism)."

Apart from redefining bruxism the other aim of the paper was to suggest a grading system for the diagnosis of the activity. In addition, they proposed use of the terms 'Awake bruxism' and 'Sleep bruxism' to describe the activity, together with retirement of certain words often used in relation to bruxism: parafunction, gnashing, rhythmic, spasmodic, movement disorder, oral habit, and the adjectives diurnal and nocturnal. This paper provoked considerable debate on the subject including one of the original authors advising during a conference "...be wary of consensus papers, they are not scientific" (22).

In 2016 two separate groups of the original authors wrote commentary papers. In the first one, the question was posed "Is bruxism a disorder or a behaviour?" (23). It is only a disorder if it has negative health outcomes. If it is a behaviour, not necessarily needing clinical treatment, then the diagnostic grading system is not appropriate. They acknowledged that the literature regarding AB

is more limited than that related to SB and therefore restricted their comments to SB. The second group of the original authors responded, “Why not stop looking at bruxism as a black/white condition?” (24). They consider bruxism as an umbrella term which groups different activities with different aetiologies, featuring differing activities of the jaw muscles and consider it to be a phenomenon mirroring underlying conditions. They note that we can all tense our jaw muscles at times when concentrating on various tasks. They suggest bruxism should be viewed as a disorder, i.e. a condition needing management or prevention, only if it has consequences. They conclude that research should work towards a valid construct for viewing bruxism as either a phenomenon, a disorder or a behaviour.

The first group of authors responded that in the framework that they proposed, when bruxism only occasionally leads to harmful consequences, it should be seen as a risk factor rather than a disorder. They felt that if bruxism is considered as a disorder ‘only when it has consequences’ it could lead to over treatment (25).

The outcome from these commentaries, together with a gathering of bruxism experts from around the world in San Francisco in March 2017, was published in 2018 as *“International consensus on the assessment of bruxism: Report of a work in progress”* (2). As of September 2023 this has 512 citations in Web of Science.

The authors conceded that while the new definition for bruxism was widely accepted, it should be updated and separate definitions for AB and SB should be developed. Also, the grading system, outlined in the 2013 consensus paper, provoked exchanges on its practicality and appropriateness and needed re-examination. New definitions were written separately for AB and SB; both begin with “masticatory muscle activity” and end with “in otherwise healthy individuals”. The definition for AB includes tongue thrusting with no tooth contact.

New definitions: - “Sleep bruxism is a masticatory muscle activity during sleep that is characterised as rhythmic (phasic) or non-rhythmic (tonic) and is not a movement disorder or a sleep disorder in otherwise healthy individuals.”

“Awake bruxism is a masticatory muscle activity during wakefulness that is characterised by

repetitive or sustained tooth contact and/or by bracing or thrusting of the mandible and is not a movement disorder in otherwise healthy individuals."

The original grading system was also modified. In their conclusions the authors state that in otherwise healthy individuals, bruxism should not be considered as a disorder, but as a behaviour that can be a risk factor (and possibly a protective factor) for adverse health consequences. Finally, they concede that "cut-off points for establishing the presence or absence of bruxism should not be used in otherwise healthy individuals; rather, bruxism-related masticatory muscle activities should be assessed in the behaviour's continuum." The debate will continue. Further classification into primary and secondary bruxism has been suggested (26). Primary bruxism being of unknown or uncertain aetiology, whereas secondary bruxism is attributable to a known aetiology such as Parkinson's disease, epilepsy or drug intake.

In a recent addition to the commentary on definition and classification, a letter to the editor of the Journal of Oral Rehabilitation by Svensson and Lavigne, suggests the use of two new terms. Bruxism, either awake or sleep, showing no signs, symptoms or impact on general health could be called "Normo-bruxism". While bruxism causing any pathological consequence could be termed "patho-bruxism" (27). In a following letter, other authors disagree. They refer to the 2018 consensus paper (2) and state that bruxism can be both harmful and beneficial in the same individual and dichotomising the description does not work. They prefer using terms such as 'harmless behaviour', 'risk factor' and 'protective factor' in describing possible consequences of the behaviour (28).

1.3: RATIONALE FOR THESIS

In the scientific community dealing with bruxism, SB is the wealthy uncle in the big house on the hill, where AB is the poor, recently discovered brother, barely surviving in a crumbling shack in the village. If we consider that we sleep approximately 6 to 8 hours per night, therefore we are awake 16 to 18 hours, a difference by a factor of between twice and 3 times, there is significantly more opportunity for awake bruxing activity to go on in 24 hours than sleep bruxing. Whenever studies have figures for the incidence of each form of bruxism, AB almost invariably has a higher figure

than SB. Perhaps because SB is more readily measurable by accommodating subjects in a clinic overnight and wiring them to measuring devices. Both forms are spasmodic and cyclical, an added complication to assessment.

The numerical imbalance between the two volumes of literature for the two forms of bruxism is still surprising.

For most of the 19th and 20th centuries the word bruxism was used indiscriminately for grinding or clenching teeth without specification as to whether it was awake or asleep. There were occasional voices in the wilderness to the contrary (17).

As a broad generalisation when dentists in general practice see evidence of teeth wear, they suggest an oral appliance, commonly called an occlusal splint or night guard, be worn by the patient at night to prevent further teeth wear.

Increasingly toward the end of the 20th century and up to now, AB and SB are separated. Statements regarding their occurrence or aetiology invariably express them in two different ways or with two different percentages. Hence the probable need for a different treatment or management regimen for each form of bruxism. The other clear message in much of the AB literature is about the need for much more research. A greater volume of it and of an improved quality. In order to make recommendations for the future, this systematic review will examine the past.

So, what is the literature suggesting as forms of management for AB?

What is the quality of the research that makes these suggestions?

Is there a suggested basic minimum form of care for AB?

And how do other forms of management that are referred to in the literature compare with the suggested basic minimum?

The purpose of this systematic literature review and thesis is to answer these questions.

1.4: HISTORY OF AWAKE BRUXISM

1.4.1: ANCIENT

> *"Aspasius' wife, the woman with quinsy, the woman who lived over the gate: 'her jaws were clenched, and the teeth could not relax themselves more than the width of a probe'"*
> *The Book of Prognostics – Hippocrates 400BCE*

As much of the commentary on Awake Bruxism links it to psychosocial factors (29), (30), it would

be tempting to think that AB is a 20th or 21st century phenomenon related to the steadily increasing pace and pressures of life. History and literature suggest otherwise.

In November 2018 The British Museum opened a special exhibition in London entitled *"I am Ashurbanipal: king of the world, king of Assyria"*. King Ashurbanipal was one of the last kings of the Assyrian empire in the 7th century BCE 668 – 627. Whilst being a great king and warrior, he was equally proud of his scribal education and was able to read cuneiform script in Akkadian and Sumerian. He built a large library at Nineveh (near Mosul in present day northern Iraq) predating the Great Library at Alexandria by some 300 years and filled its many rooms with clay tablets collected from across his empire. Some of these tablets, dating from the Sumerian civilisation, 4100-1750 BCE, contained medical records. At the end of the 7th century BCE the fire which destroyed the library preserved the tablets, only exposed by archaeologists approximately 2000 years later in the mid-19th century. Among these tablets, now held in the British Museum, are some devoted to medical and dental problems. For example: -

> *"If he grinds his teeth the disease will last a long time".*
>
> *"If he grinds his teeth continuously and his face is cold, he has contracted a disease through the hand of the Goddess Ishtar"* (31).

Possibly as early as 4100 BCE there was awareness of tooth grinding and its effect on the human body.

The phrase "wailing and gnashing of teeth" *("fletus et stridor dentium"*) would be familiar to many people brought up in the western Judeo-Christian tradition. Variations of it are in the Old Testament, much of which is derived from the Jewish Torah, in Psalms dating from the 7th C BCE (psalm 35) *"Like the ungodly they maliciously mocked; they gnashed their teeth at me*." In the New Testament the same phrase occurs in The Gospels of Matthew and Luke. Matthew 8: 12, (AD 70). The significance of the Old Testament references is the evocation of the guilt of sinning, and the consequent threat of hell. Hell will be a place of endless anguish, remorse, pain and misery linked to wailing and gnashing of teeth. The New Testament references using a similar phrase threaten that

those who do not belong to Christ will suffer a terrible fate. The misery that causes the gnashing of teeth will be unknown in heaven by true followers. The ancient Greeks, Romans and other cultures were familiar with bruxism. "*Grinding or gnashing the teeth seems to occur mostly as a symptom of a graver pathological condition." "To grind the teeth in fevers when this has not been a habit from childhood, signifies madness and death*" (32). The Roman senator and philosopher Seneca the younger's poetic description of anger – *".....blood rushing from my heart, my lips are shaking, teeth grinding, hair bristling and rising, my breathing is a thick wheeze"* (33). From a translation and commentary of The Bhagavad Gita: *"…….Is this the end of time? Is this finality? The fires are raging; the teeth are gnashing; the faces are contorted*." (34). "Wailing" and "gnashing" links tooth clenching or grinding to painfully strong emotion. This link continues to the present day. Much of the research into bruxism in the last half century has been directed towards analysing the association between bruxism and physical pain. Also, researchers have examined psychological and emotional factors to establish what role, if any, they play in the aetiology of the behaviour.

1.4.2 19TH CENTURY

King Stannis Baratheon grinds his teeth regularly, so loudly it can be heard "half a castle away". In George R. R. Martin's Game of thrones; first volume of A Song of Ice and Fire series. Wikipedia

In 1837 Professor Robert Graves, well known surgeon and medical educator after whom the thyroid condition is named, wrote in the Dublin Medical Journal of March 1836 regarding patients with *"the morbid habit of grinding the teeth*". He observed that they were all "*... persons of a gouty diathesis*" frequently with "*teeth worn down to the level of the gum*". His suggested cause for bruxism, a central rather than peripheral one, he also linked to a second cause for the resulting tooth wear, a change in salivary pH, again of central origin (35).

In 1860 an editorial in the Southern Dental Examiner talked of tooth wear caused by bruxism and the ultimate loss of teeth if it is left unmanaged (36). The link between tooth grinding and emotion was taken up by Charles Darwin. Darwin described that in a man suffering from pain "…. *the mouth may be closely compressed or, more commonly, the lips are retracted with the teeth clenched or ground together*." He observed similar reactions in his study of the emotions of animals (37).

The precursor to the Journal of the American Dental Association (JADA), a publication named Dental Cosmos, started in 1859; it recorded and debated the earliest years of the profession up to 1936 when it merged with the JADA. The dental science writing of the late 19th C and early 20th C consisted principally of clinicians writing of their experiences with patients, case studies and their opinions regarding diagnosis and treatment. Articles such as those by Parmele, Jeffery, Marie & Pietkiewicz, Quedenfeldt, Stillman, Tischler and Frohman (38), (39), (40), (41), (42), (9), (17) appeared in Dental Cosmos.

CHAPTER 2: AIMS & LITERATURE REVIEW

2.1 AIMS

The PICO (Participants, Intervention, Comparator, Outcome) question forming the basis of this study is as follows: -

"For teenage and adult humans (aged 13 and above), how effective is the most frequently evaluated form of management to reduce awake bruxism behaviour compared to other interventions?"

P: The participants being studied are teenage and adult human beings aged 13 and above.

I: The intervention is the most frequently evaluated form of management to reduce awake bruxism behaviour.

C: The comparator is: no treatment, placebo treatment, any other intervention to manage and to reduce awake bruxism behaviour.

O: The outcome is managing or reducing awake bruxism behaviour.

The literature review in this chapter is a broad review of bruxism literature, starting in 1900 and

coming up to the present day presenting a background to AB. Knowing what has happened in the past or maybe more importantly what has not happened, gives us an understanding of present attitudes and informs our view for the future.

What is the most frequently investigated form of treatment or management for AB in the literature?

What other forms of treatment or management are investigated and how do they compare with the most frequently mentioned one?

The aim of the systematic review is to cast a broad net, collect all information relevant to the PICO question, then filter, sort and analyse sufficient to answer that question.

2.2 THE ROLE OF SYSTEMATIC REVIEWS

In an essay entitled "Doing new research? Don't forget the old" the writer refers to our present day information overload and discusses the options for working our way through it to retrieve the information that we seek, being sure it is unbiased and reliable. He quotes Lord Rayleigh (eminent physicist, discoverer of Argon and recipient of the Nobel prize) at a meeting of the British Association for the Advancement of Science which took place in Montreal in Canada in the late 1800's.

"'*If, as is sometimes supposed, science consisted in nothing but the laborious accumulation of facts, it would soon come to a standstill, crushed, as it were, under its own weight. …. The work which deserves, but I am afraid does not always receive, the most credit is that in which discovery and explanation go hand in hand, in which not only are new facts presented, but their relation to old ones is pointed out*." (43)

This is the role of the systematic review. The systematic review has been defined by Cook and colleagues as:

"*the application of scientific strategies that limit bias to the systematic assembly, critical appraisal, and synthesis of all relevant studies on a specific topic*."(44)

A strictly disciplined search system engages with the general literature to retrieve anything relevant to the PICO question. A protocol is developed to answer that question, analyse the data and make objective conclusions.

2.3. LITERATURE REVIEW

2.3.1 EARLY 20TH CENTURY

At the Galileo Museum in Florence, extensive worn surfaces of a premolar reveal his tendency to bruxism. Teeth tell tales long after death. - Anon.

In 1901 Dr. Jeffery from Perth in Western Australia wrote in Dental Cosmos under Hints Queries and Comments, that he had a patient "*who, living in a boarding house drove all his neighbours away from his allotment by reason of the furious gnashing and grinding of his teeth at night during sleep."* He discussed his treatment for the patient, which will be outlined later in Management and Treatment and goes on to ask what else could be done.

An editorial in Dental Cosmos in 1902 (45) refers to "*Gnashing of teeth*" having a partly hereditary cause. Reference is made to our animal ancestors, in the presence of an enemy, lips drawn back exposing gnashing teeth, fighting, causing or suffering pain.

One of the earliest and most frequently cited scientific references of the 20th century, is by Drs. Marie & Pietkiewicz (occasionally mis referenced as Dr Marie Pietkiewicz). The original article, in French, appeared in the 1907 Revue de Stomatologie under the title "La Bruxomanie" (8). It was summarised in Dental Cosmos of the same year (40). This paper is often cited by authors of bruxism articles in their history section, because it is the first recorded use of the word bruxomania; the word bruxism being derived from it. In a translation from the original French (46), many more interesting details are revealed.

The authors used the term "La Bruxomanie", bruxomania, to describe the awake bruxism (AB) they observed in 13 of their patients who were inmates of the asylum at Villejuif in southern Paris.

Patients are described individually; all were suffering serious mental conditions. Dr Marie was the medical superintendent of this asylum for several years. He acquired a collection of art works made by the inmates of the asylum and developed a reputation for managing patients with the use of art. *"Some bruxomaniacs grind their teeth for only a few moments each day, others for entire days, weeks and months." "In some cases, it ceases and disappears spontaneously, and in others it persists until death."*

The two doctors distinguish between "trismus", gritting or clenching teeth, as a "contraction tetanique" and bruxomania, grinding teeth, as a "contraction clonique" which involves more extensive use of facial musculature. Their descriptions are of a daytime activity that in some patients continue into the night and sleep. They describe it as contagious. One patient would start, subsequently it spread to others, moving along the ward sometimes skipping a bed. When the originating patient stops so too gradually will the successors. They observed that this Awake Bruxism could be stopped by instruction from a member of the staff. They describe the night-time noise from grinding as worse than snoring for interrupting the sleep of others. Often teeth are worn down to the gum. The condition is nearly always associated with a definite or transitory aphasia, or with a problem with words.

When I appear in public people expect me to neigh, grind my teeth, paw the ground and swish my tail - none of which is easy. - Princess Anne

It was at this time in the history of bruxism that the link between it and periodontal disease received increasing attention. In 1908 Quedenfeldt writing about 'Pyorrhoea Alveolaris' (periodontal or gum disease) said he had first heard of it being caused by malocclusion from Dr Karolyi (whose name was briefly used to describe bruxism). His theory was that bruxism ruptured the tissue around teeth leading to bleeding and the formation of deposits which acted as foreign bodies causing 'Pyorrhoea Alveolaris' (41). It established a theoretical or conceptual link between bruxism and periodontal

conditions which has persisted through to the present day (47). This was at a time when the germ theory of disease had been suggested by Pasteur. It was applied to periodontal disease when Adolph Witzel identified bacteria as a cause of "pyorrhoea" (48).

Another author theorised that because of the continued grinding of the teeth certain groups of brain cells had developed a psychic thirst for these stimuli. If the stimuli could be temporarily arrested, then the impulses needed to produce them would cease to emanate from the centres involved (49).

The management of 'Pyorrhoea' was described as a three-pronged attack with selective tooth grinding to manage traumatic occlusion as a very important second step (42). In a translation from the original German, Bodecker describes the unusual number of cases of grinding the teeth in 1917 near the end of the first World War. Referring to the volunteer corps of nurses and attendants being unused to the sight of bad wounds. Their coping mechanism is to *"…. occlude the teeth with unusual force to assist in maintenance of normal equilibrium……"* He divides the causes into *"……. nervousness, either permanent nervous temperament or temporary nervous irritability."*. A century later while the terminology has changed the human emotions are the same. A permanent nervous temperament is termed trait anxiety and temporary nervous irritability is renamed state anxiety. He suggested that if someone grinds during the day, inform the patient's friends of the damage it can cause and enlist their co-operation in preventing it (50).

"He had been full of the idea so long, dreamed it through to the end, waited with his teeth set, so to speak, at an inconceivable pitch of intensity." The Great Gatsby - F. Scott Fitzgerald.

2.3.2 WORLD WAR 1 TO WORLD WAR 2

In the period between the two wars several issues were under discussion in relation to bruxism: the relationship to periodontal disease, traumatic occlusion, dental occlusal adjustment to deal with these two factors; the rest position of the mandible and the involvement of psychological issues.

In a paper by Orban (51) discussing individual cases, the tissue changes in relation to traumatic occlusion were explained. It is assumed that this included bruxism. These changes were verified some years later by work with co-workers (52).

The discussion of the nature of the relationship between bruxism and periodontal disease had changed slightly. Previously authors were quite definite about bruxism causing periodontal disease. Now the thinking was that bruxism was a causative factor in periodontal disease but not the only one, it was acknowledged that other 'irritants' were at work (9). This author is one of the first to discuss bruxism as a habit. In another paper the concept of 'habits as petrified thoughts' is proposed (53).

Dental occlusal adjustment as a treatment for bruxism which in turn treated periodontal disease was common to many papers of this era (54), with some authors describing their adjustment regimen in detail (55), (53). The rest position of the mandible is discussed by one author who concludes that "four thirty seconds of one inch" is the most common distance between rest position and centric occlusion as measured using a mark on the chin. He stressed that this is particularly important in denture cases and that errors may lead to traumatic occlusion (56).

A paper by Frohman published in 1931 (17) on "The application of psychotherapy to dental problems" is notable for several reasons. The author was an M.D. and psychotherapist. The Oxford English Dictionary quotes his paper as the first known use of the word 'bruxism' (16). Although stating that pyorrhoea was symptomatic of bruxism (on the advice of dental colleagues) and describing bruxomania as a psychic state which needed gastro-intestinal investigation prior to psychic treatment, he had some 21st century ideas. He was probably the first writer to distinguish between awake and sleep bruxism. He called awake bruxism 'occlusal neurosis' and sleep bruxism he defined as "occlusal stress during sleep". He outlined a case where once the awake bruxism was managed the sleep bruxism was brought under control too. This is one of the earliest references to 'carry over' – managing sleep bruxism by reducing awake bruxism. He was another author who

talked of bruxism as a habit and called for greater co-operation between dentist and physician. Referring back to Frohman's paper Boyens also talked of 'carry over', suggesting that his patients make positive affirmations whilst awake in order to reduce nocturnal bruxism. He also advocated treatment of bruxism with dental occlusal adjustment (54).

"There are times when my longing for you overwhelms me […] so often I can think of you only with teeth clenched." – Franz Kafka, letters to Felice

2.3.3 POST 2ND WORLD WAR

Quicker and quicker she danced, till she lashed herself into such a fury of excitement that the foam flew in flecks from her gnashing jaws, till her eyes seemed to start from her head, and her flesh to quiver visibly. King Solomon's mines – H. Rider Haggard

In the post-World War 2 period writing about bruxism continued in a similar way to pre-war with the link to periodontal disease and the need for dental occlusal adjustment (57), (58), (59), (10), (60), (61), (62), (11), (63). The war accelerated the development of psychosomatic medicine. Many doctors witnessed the link between psychological causes and physical effects, with authors writing about the need to have regard for psychological and emotional factors (64), (65), (66). Vernallis (67) confirmed a relationship between anxiety, hostility and hyperactivity in bruxing patients The rest position of the mandible and the negative effects of encroaching on it are discussed by some authors (68). Throughout the 1950's the developing views of dentistry and dental treatments became increasingly mechanistic.

2.3.4 1960's

"And the wild things roared their terrible roars and gnashed their terrible teeth and rolled their terrible eyes and showed their terrible claws." Where the Wild Things Are - Maurice Sendak.

This decade saw several major developments in the bruxism literature. In 1960 in a section of The Lancet entitled "Points of View" Every first outlined his theory about extreme movements of the mandible and the reasons for them (69). He maintained that humans moved their mandibles from a centric relation position to an extreme lateral or anterior position and so sharpened their teeth. He wrote that "*most mammals sharpen their teeth"* without quoting a reference to support the statement. In subsequent papers he cites his own unreferenced statement to justify the claimed fact. Every disputed the pathological theory of bruxism. His theory was that this instinct had become culturally unacceptable and was suppressed soon after birth. He linked repressed aggressiveness with the elimination of eroticism prior to matrimony. Having started with a dental problem the dissertation broadened to include sexual repression. As the instinct appears during sleep it is therefore merely repressed. Thus, an emotional conflict becomes physical with the development of facial pain.

In later publications (70), (71), (72) Every named his theory "Thegosis" from Greek *θηγός* "thegos" meaning sharp and talked of the use of teeth as weapons that needed sharpening. He named the science related to it 'Thegotics' which he defined as *'the science that deals with the morphological, functional and behavioural aspects of thegosis and the treatment of its related physical, emotional and social pathologies.'* Bruxism he refuted as a mal-adapted theory full of myth.
Some authors (73) supported his theory, others (74) refuted it. In 1983 Anderson (75) wrote about the importance of Thegosis, criticising the concept of bruxism, describing it as 'nonsensical'. This attitude of intellectual superiority, intolerance of the views of others and poor scientific argument, characterised much of the writing by the supporters of 'Thegosis' (76), (77), (12).
In 1998 Young (78), an oral pathologist, criticised the theory of Thegosis, describing it's originator as "*an egregious dentist from New Zealand"*. He talked of him as a dental Don Quixote tilting his Thegosis lance at bruxism. In common with other later authors (13), (79) Young wrote that the Thegosis theorists had their direction of mandibular action 180° wrong. Microwear studies showed

that the mandibular movement in tooth wear was from a lateral position back to centric relation not the reverse. They also suggest that an evolutionary purpose of bruxism may be the strengthening of masticatory muscles. This would only take days whereas tooth sharpening would need a much longer time.

Six musicians entertained Mona Lisa Gherardini while he painted. (Some say her one-sided smile was a result of bruxism, ……others say her face was his own.)

'Da Vinci was a bastard', Joe Dolce

The second significant development of the 1960's was a paper by Ramfjord (80).

It would be hard to overstate the influence that this study had on clinicians, their thinking and their attitude to treatment. The dental occlusal adjustment approach to treatment for bruxism which had been developing for many years now appeared to be confirmed by a scientific study. This thinking continued to affect subsequent generations through to the present day (81). It reinforced a mechanistic view of patient dental management confirming the theories about bruxism that had developed in the early part of the 20th century including its relationship to periodontal disease. The author being a professor of periodontology. Perhaps his undoubted reputation and authority within the profession was also a factor.

This was one of the earliest bruxism studies using electromyographic (EMG) recording equipment on a group of patients. The article is extensive with numerous images of EMG tracings. In the study 34 patients, with a diagnosis of bruxism, were examined. Dental occlusal adjustment was carried out on all patients to correct the discrepancy between centric relation and centric occlusion. Particular attention was paid to muscle activity during swallowing. Bruxism no longer occurred in all 34 patients. The author concluded that bruxism may be started by any dental occlusal interference together with nervous tension but more significantly that dental occlusal adjustments eliminated bruxism.

Several faults have been identified in this study. There was no description of the diagnostic criteria in the selection of subjects. There was no control group. Nocturnal bruxism was not dealt with

directly, the EMG recordings were taken during the day. There was no scientific evidence given for the link between dental occlusal interferences and bruxism, it was the authors 'observation' that dental occlusal adjustment eliminated bruxism. His further 'observation' was that removal of centric and balancing side interferences were more important than working side and protrusive interferences.

The third significant development in research in this decade was a study on sleep bruxism (82). This has been described by later researchers as the first controlled sleep laboratory study (83). The authors observed that while there was an increase in heart rate at the same time as bruxism occurred, it was transient and did not outlast the bruxism episodes. This agreed with Takahama's study earlier in the decade (84).

Clinical examination of participants did not find evidence to support dental occlusal interferences as a cause of bruxism. This was again in agreement with Takahama who had written: -

"..... the role teeth play in bruxism is no more than the component to emanate sound"

They did not support the theory that sleep bruxism is related to emotional or personality problems.

They disputed Every's adaptive theory, describing bruxism as maladaptive in view of the tooth damage it causes.

As sleep bruxism is transient, they suggest that investigations of management strategies for the condition would need sleep laboratory studies over an extended period.

Lastly, they recommend that all bruxism research should separate AB and SB.

A small study set out to demonstrate the link between daytime tooth clenching and mental stress (85). They concluded that there was a direct relation between a stressful situation and an increase in masticatory muscle activity.

Other researchers at that time maintained the link with periodontal disease (86), (87); one described bruxism as a habit, stressing the psychological aspects of it as well as outlining three types of bruxers AB, SB and combined AB/SB (88). Nadler, a frequent author on bruxism, contended that bruxism occurs at all ages (89), while Graf stressed the lack of awareness that people have of the

habit, he thought that most patients will stop bruxing once their dental occlusions are adjusted and oral appliances, such as occlusal splints, would only be needed for extreme cases (90). The same group of researchers who initiated the first controlled sleep laboratory study summarised the negative effects of bruxism, again could find no significant association between SB and dental occlusal factors and recommended that the evaluation of any therapeutic measure should be carried out in a sleep laboratory (91).

Olkinuora reviewed the literature, discussed studies and suggested some new hypotheses. He considered bruxism as a concept was somewhat ambiguous and lacked definition. He referred to The Copenhagen School of Dentistry's proposed concept in which there was no difference between AB and SB, the emphasis was on the unconsciousness of the activity and that it need not be pathogenic. He described bruxism as a "universal phenomenon" forming a continuum with "normal" at one end and "pathological" at the other, dependant on the intensity and persistence of the habit and stated that drawing a line between the two was difficult. He labelled nocturnal bruxists as "genuine bruxists" and diurnal bruxists as "stress bruxists" but conceded that a hard line could not be drawn between the two as there is a degree of overlap (92).

Now set the teeth and stretch the nostril wide, Hold hard the breath and bend up every spirit to his full height. On, on, you noblest English. Henry V - William Shakespeare

2.3.5 1970's

Scientific writing was moving more towards interpreting the results from clinical studies and away from individual writers' thoughts or theories.

Research on alternative forms of treatment or management for bruxism appeared in this decade. Biofeedback was favoured (93), (94), (95) with some very good results. It was found that biofeedback more consistently reduced bruxism than dental occlusal adjustment. Massed Practice

eliminated bruxism for 11 out of 14 patients (96) and habit reversal was used successfully for oral habits including soft tissue bruxing and tongue thrusting (97).

Forgione used a plastic laminated mouthguard made of four polyvinyl sheets of differing colours, total thickness of 0.508 mm, to develop a technique for measuring the volumetric magnitude of bruxing behaviour (98).

In a critical review of bruxism, a psychologist's involvement in the research of these 'dental' problems was considered to be valuable; bruxism could be looked at as a psycho-physiological disorder (99). The two authors also advised that more information is needed on 'diurnal' bruxism. 45 years later there is still a dearth of research dedicated to Awake Bruxism (23), although in the last few years the situation has improved considerably.

The same authors wrote later suggesting that behavioural procedures could be effective in the management of AB along with dental occlusal adjustment (100). A similar view was taken by Mikami who theorised that the future therapy for bruxism may be more behavioural than mechanical. He further stated that bruxism is managed not treated (101). A very 21st century idea.

The question was posed "Is bruxism a nutritional problem?" In a study of 91 dentists and their wives, bruxism was stopped in the subjects who increased their consumption of calcium and vitamin B5. While the authors conceded that their observations were only circumstantial they thought that they merited a future well-constructed double blind trial (102).

The decade concluded with Nadler writing a summary of the subject, starting with a definition and moving on to various aspects of treatment including the need for dental occlusal adjustment to make centric occlusion coincide with centric relation. He concludes that one of the major causes of bruxism concern an individual's personality and that unchecked bruxism could result in premature damage to the dentition (103).

".....such senseless wicked rages. There she lay dashing her head against the arm of the sofa, and grinding her teeth, so that you might fancy she would crash them to splinters!"

Describing Catherine in Wuthering Heights by Emily Bronte

2.3.6 1980's

This decade saw the duel continue between peripheral and central, tooth muscle theory and psychophysiological theory in the aetiology of bruxism, MFP and TMD.

In a study of bruxers who were deliberately given a restoration with a dental occlusal interference, it was found that dental occlusal interferences have little or no effect on the level of SB (104). The authors question how the belief that dental occlusal factors initiate SB originated and what evidence has sustained it, acknowledging that one article (80) is frequently cited uncritically. Ramfjord looked at AB and drew conclusions for SB. They stressed the separation of the two entities.
Some opinions were stated quite definitely. In reviewing studies on mandibular dysfunction in general, criticism was made of any link with morphologic disharmonies made by epidemiologists. They will be "*..perpetuating this mechanistic nonsense for yet another generation of dentists."* (105).
Dental occlusal adjustment had no consistent effect on bruxism (106).
A Finnish researcher, referred to earlier, conducted research which would nowadays be considered ethically dubious; carrying out non-reversible, prophylactic treatment i.e. dental occlusal adjustment, on subjects as prevention for a condition the symptoms of which were not yet apparent. Although not directly concerned with bruxism it adds to the discussion on occlusal adjustment. 62 dental students, none of whom needed treatment for CMD/TMD were divided into 2 groups. One group received dental occlusal adjustment, the other a mock adjustment such as polishing fillings or holding the head of a rotating handpiece against a tooth. Two years later all subjects were evaluated. Most students in the study group exhibited dental occlusal interferences. The control group (mock adjustment) had more subjective symptoms than the study group. Their conclusions were: removing dental occlusal interferences in young adults (none of whom needed treatment) has no harmful effects and that dental occlusal adjustment reduces subjective symptoms of CMD and possibly clinical signs too (107). A decade earlier the same author had written: *"The prophylactic*

grinding of teeth also lacks a rational basis"(108).

An auditory feedback signal was used together with a 2-3-minute arousal task studying 10 'heavy' bruxers . They were only able to follow up on 7 subjects. Of them 4 reported minor tooth pain and were aware of daytime tooth clenching (AB) which was unaffected by the feedback treatment. As AB would definitely generate some symptoms they thought that in some cases the feedback should be used as a 24 hour treatment (109). This is one of the first studies hinting at an interrelationship between AB and SB, but of an undefined nature.

This time in the 1970s and 1980s was popular for the use of biofeedback in its various forms in clinical research. Audiostimulation and electromyographic biofeedback were used in one study for 33 patients split into 2 groups according to the evolution and duration of their symptoms. Group 1 less than 1year, Group 2 more than a year. 14 sessions, 5 per week, each divided into 3 x 15 minutes.

They concluded that the combination of Audiostimulation and EMG biofeedback effectively reduced symptoms in both patient groups (110).

Rosenbaum and Ayllon treated bruxism with a habit-reversal technique. They only describe 4 patients, each with a different problem. But reductions in the frequency of the behaviour were achieved in each case and maintained over 6 and 12 month follow ups (111).

Prior to discussing the details of their technique, they mention various previous ways of managing bruxism:

Dental occlusal adjustment, occlusal appliances (e.g. bite plates, night guards), the effectiveness of which has not been demonstrated in a controlled way (99). They mention other approaches; supplementing the diet with magnesium during periods of growth or extreme stress, drug therapy with muscle relaxants or tranquilizers, psychotherapy to resolve any underlying, causative conflicts. All have either proven unsuccessful or no data has been presented on their efficacy.

Comparing habit reversal and negative practice treatment in the management of oral habits, it was shown that habit reversal was more successful (112).

With subjects somewhat reminiscent of the individuals in Marie & Pietkiewicz study in 1907, researchers were able to reduce AB in 2 profoundly mentally retarded patients using the punitive technique of 'icing', the application of ice to areas of the face. However the reduction in AB did not last beyond the period of the trial (113).

The relationship between AB and SB was studied further by researchers comparing stress reduction counselling and EMG feedback for SB. They concluded that using stress reduction whilst awake influences SB during sleep as well as the potential to reduce AB. They also thought that stress reduction therapy was much less intrusive than EMG feedback (114). This is one of the earliest papers that, whilst distinguishing between AB and SB, hints at a link between them. Treating or managing AB can influence SB.

A comparison was made between the intensity of conscious clenching and that of bruxing in 10 subjects who were bruxers. All 10 subjects bruxed with an intensity greater than maximum conscious clenching (115).

The difficulty of identifying bruxism due to the lack of awareness in many patients, together with tooth wear, tooth mobility, fracture, intrusion, extrusion, opening of tooth contacts, drifting, damage to restorations and possibly erosion, abrasion and pulp pathology, are all effects on teeth that can be due to bruxism (116).

An investigation of the incidence of AB and SB in 1052 students by Glaros, found 21.2% were current bruxists, 3.3% were nocturnal bruxists and 4.5% were combined AB/SB. The last group was a distinct subgroup not merely a combination from other groups. It was thought that the differentiation into 3 groups had considerable usefulness both practically and theoretically (117).

This is one of the first references in the literature since Walsh (88) to 3 groups of bruxers AB, SB and combined AB/SB.

Several authors reviewed bruxism. "The Bruxer" by Sayers (118) was also presented at the RACDS Convocation in Melbourne in 1986. It covered aetiology, diagnosis, the effects of bruxism and treatment. Bruxism is prevalent in the community and should be diagnosed and treated early before too much tooth destruction. His aim was that treatment should reduce the damage to "*tolerable limits"*. Rugh and Ohrbach wrote a chapter on Occlusal Parafunction in Textbook of Occlusion (119). They covered all aspects of bruxism and included a diagram of the effects of it on face, muscles and teeth. They distinguished between AB and SB and suggest that the diagnosis and management of AB requires time, questionnaire, interview and pain charts, all designed to involve the patient in the management of their condition. SB and temporomandibular disorders were examined together with the nature of SB, it's prevalence, aetiology, diagnosis and treatment. As SB is variable night to night and symptoms appear and then resolve, diagnosis can be difficult requiring several visits even several treatments. An occlusal splint is usually needed for long term management (120).

In a study of oral habits as factors in head and facial pain in 125 undergraduate psychology students, clenching and jutting jaw forward produced more pain than cupping the chin and jutting the jaw to the side (121). Rugh, a very frequent contributor to the literature at this time, posed the question in relation to MPD: "*is the patient's anxiety as a result of the pain or is it the cause of it"*(122). In an interesting side issue, the same author examined the relationship of jaw muscle activity, rest vertical dimension and clinical rest position (CRP). He and his co-author found that the mandibular position of 1 to 3mm. of interocclusal distance measured phonetically, which has been referred to as "clinical rest position", is not a position of rest and that there is approximately 6mm difference between it and a point of minimal EMG activity (123).

A link was made between oral habits and some migraines, together with the treatment of oral behaviours with habit reversal techniques. It was concluded that some forms of head and face pain develop as the result of oral habits (124). The significance of oral habits was covered in detail in a chapter in "Behavioural Health. A handbook of health enhancements & disease prevention". An elegantly simple drawing of the side of a face with arrows pointing to each of the consequences of oral habits, starts the discussion.

The authors refer to public awareness strategies together with oral hygiene instruction that has reduced levels of periodontal disease and caries, and contrast that with the minimal attention given to the detection and changing of damaging oral habits. The suggestion is made that greater attention should be paid to the early detection of these common problems together with strategies to modify them (125).

"Since we're going to suffer, let's clench our teeth," she said. "Pain like that, pain of the soul, does not go away with remedies, therapy, or vacations; you simply endure it deep down, fully, as you should" Isabel Allende. Featured in Isabel Allende quotes

2.3.7 1990's

The decade was bookended by review articles; the first was a two-part review of the bruxism literature starting with the lack of agreement on definition, aetiology and conceding that aspects of treatment were controversial. The fact that bruxism is not a recent phenomenon having been referred to in very early times and that it is managed not treated. The author concluded that most researchers agreed that psychogenic and dental occlusal factors were the main aetiological components (52), (126).

At the end of the decade there were two review papers. *"From bite to mind: TMD - a personal and literature review"*. Although this and the following paper concern TMD it has some relevance to bruxism. The author opened with a quote from the English philosopher Augustus De Morgan which

he felt illustrated much of the debate about TMD over the years and could as well be applied to bruxism: "*I don't quite hear what you say, but I beg to differ entirely with you."* (127). He goes on to say physiotherapy and cognitive behaviour therapy are replacing dental occlusal treatments. In reference to the widely accepted attitude to dental occlusal equilibration he quotes Mark Twain: *"If your only tool is a hammer, you may treat everything as nails"*. He questioned why the belief in dental occlusal factors being the aetiology for TMD survives and thinks the reason is that most patients have some bite disturbance or dysfunction, but mostly without any complaints. *Put simply, the focus must be shifted from the bite to the mind."* (128)

"In a similar vein, the second review paper at the end of the decade was a qualitative systematic review of randomised controlled trials regarding dental occlusal treatments for TMD. The authors expressed surprise at the lack of good studies in a field with a long history of vigorous debate, which did not seem to be calming down. They concluded that there may be some benefit in the use of occlusal splints, but there was no evidence for the use of dental occlusal adjustment (129).

2.3.8 2000 to 2010

During the latter part of the 20th century and increasingly in the 21st century, researchers realised that awake bruxism and sleep bruxism are separate entities meriting separate consideration. From now on this review will deal only with awake bruxism.

Another change that is noticeable moving forward is that as research becomes more sophisticated and the way it is reported more complex, there are an increasing number of papers with multiple authors and a decreasing number with single authors. The nature of research and the way it is written about, becomes increasingly collaborative.

Piquero and Sakurai stressed the importance of the identification (and by extension - management) of awake bruxism in denture wearers, as it can be the key for the stability and comfort of their prosthesis, hence the success of their dental treatment (130).

Another author, a philosopher, psychologist and geneticist wrote that the literature suggests that the splint is the most popular treatment modality for bruxism but falls short in some respects. In the early part of the 21st century some 1.6 million of them were made annually in the USA alone (131). The device does not actually prevent or cure bruxism, but he quotes an earlier author saying "*splints will protect the teeth, but will not alter the habit in the long term*" (132). In a broad ranging paper that does not profess to be detailed, a number of other approaches are mentioned: -

Sound alarms, electrical stimulation, psychotherapy of all kinds, hypnosis, massed negative practice, exercise, drugs, equilibration therapy, prolonged magnesium administration, assorted vitamins and minerals. Other intra-oral devices are referred to (133).

One writer is mentioned who thinks that intraoral vacuum formation enables long term clenching, a device to prevent the vacuum is discussed (134).

Small anterior intraoral devices such as the NTI-tss and its variants gained popularity at this time (135). Due to development of anterior open bite, time showed their unreliability.

Taste aversion was used by means of 2 small fluid filled sacks carried on a thin metal bilateral frame worn over the lower molars. Bruxism ruptured the sacs releasing an unpleasant tasting liquid (e.g. sea water) (136).

In 2008 Lobbezoo and co-workers published "Principles for the management of bruxism" In the summary they wrote "*Apparently, research into bruxism management is sensitive to fashion. Interest in studying the role of dental occlusal interventions and oral splints in the treatment of bruxism remained more or less constant over the years: between 1966 and 2007, approximately 40–60% of the papers dealt with this subject. The percentage of papers that dealt with behavioural*

approaches, on the other hand, declined from >60% in the first 2 decades (1966–1986) to only slightly >10% in the most recent decade (1997–2007). In the latter period, >40% of the papers studied the role of various medicines in the treatment of bruxism, while in the preceding decade (1987–1996), only approximately 5% of the studies dealt with the pharmacological management of bruxism." They continue "*Unfortunately, a vast majority of the 135 papers have a too low level of evidence*." They conclude that there is a vast need for well-designed studies and "*a striking paucity of evidence regarding management of bruxism*."

In view of this lack of evidence their recommendation for the management of bruxism is the so-called 'triple-P' approach: Plates, Pep-talk & Pills.

Plates – occlusal appliances, Pep-talk is for counselling, advice, guidance to increase the patient's awareness of the behaviour, Pills represents pharmacological interventions such as benzodiazepines. This type of intervention should be confined to short periods or severe cases and prescribed in close collaboration with medical specialists (137).

There is an update to this paper in 2015, in which the three 'P's are extended to five with the addition of psychology and physiotherapy (138).

A systematic review of the treatment of bruxism in individuals with developmental disabilities concluded that overall the evidence base is extremely limited regarding treatment efficacy, however a two-step process of dental screening and behavioural assessment could be recommended (139).

Another systematic review of bruxism in 2010 examined dental occlusal therapy and discussed the controversy surrounding it. They concluded "*In short, there is no support in the literature for the use of 'true' occlusal interventions like equilibration, rehabilitation and orthodontic alignment in the management of bruxism. In view of the current insights into the aetiology of bruxism that the disorder is mainly regulated centrally and not peripherally future research on this category of management strategies for bruxism seems impractical*." They moved on to review occlusal

appliances concluding that in view of contradictory results from their use and a lack of randomised controlled trials, their use should be limited to the prevention of dental damage .

The authors also refer to two other techniques for the management of bruxism, biofeedback, in particular referring to one paper claiming a 50% success with their technique and using a pharmacological approach. Regarding the latter, whilst some approaches seem promising, they conclude that they all need further assessment before clinical recommendations could be made (140).

2.3.9 2011 to 2020

This next decade was to prove highly significant with the changes in attitudes and thinking about the nature of bruxism and consequently the way it should be treated or managed.

Biofeedback was re-examined by Watanabe and colleagues. Early in the paper they say, "*Although daytime clenching is believed to be one of the oral parafunctions leading to dental problems, a treatment strategy has not yet been devised"* Their biofeedback trial only ran for 4 days with days 2 and 3 the active days of the trial, so their positive conclusion about changing behaviour is guarded regarding a long lasting effect (15).

A study conducted on mental concentration in 20 healthy participants, aimed to investigate whether teeth clenching aids performance. It was concluded that there was no benefit in arithmetic performance associated with conscious clenching. Therefore it may not be harmful for clinicians to encourage their patients NOT to clench their teeth (141).

In two case reports, patients with frontal lobe lesions resulting from acquired brain injuries developed AB. Neither patients' bruxism were helped by bromocriptine but responded to low doses of metoclopramide (142).

"Bruxism defined and graded: an international consensus" published in 2013 is one of the most significant papers related to bruxism of the decade. Although it does not deal with bruxism management per se, it is too important to omit from a literature review because it summarised the thinking around bruxism and heralded some changes. Currently it has over 600 citations in Web of Science. In the summary the authors state "*To date, there is no consensus about the definition and diagnostic grading of bruxism*". Their proposed definition was "*Bruxism is a repetitive jaw-muscle activity characterized by clenching or grinding of the teeth and/or by bracing or thrusting of the mandible. Bruxism has two distinct circadian manifestations: it can occur during sleep (indicated as sleep bruxism) or during wakefulness (indicated as awake bruxism)".* This definition is free of the drawbacks of previous ones. In addition they strongly recommend that future research clearly distinguishes which form of bruxism is being studied: SB, AB or both. In relation to a diagnostic grading system, they suggest the approach adopted for the grading of neuropathic pain of 'possible', 'probable' and 'definite' for clinical and research purposes (21).

This consensus produced considerable debate.

A paper in 2016 by some of the authors of the consensus, contributed a commentary on it. In it they discussed how the definition of bruxism emphasised it as a behaviour or an activity rather than a habit or a disorder, but how the proposal of a 'diagnostic grading system' is at odds with that as it implies that bruxism is a disorder. Finally they note that the consensus paper clearly separates AB and SB. They conclude "*Unfortunately, the knowledge base concerning awake bruxism is more limited than the literature concerning sleep bruxism (SB). Thus, our subsequent comments focus on SB"* (23).

In a letter to the editor a different group of the original authors commented further that the above commentary is too strongly orientated to defining bruxism as a behaviour but should be an umbrella term, a phenomenon mirroring underlying conditions. This would fit better with the concept of a disorder or a condition that needs management only when it has consequences (24).

In a sea of negatives about the effects of AB, there are some small islands of positives. The question was posed " Does clenching reduce indirect head acceleration during rugby contact?" Hasegawa and co-workers studied 12 high school rugby players and concluded "*After the young male rugby players were instructed to clench their masseter muscles, a marked decrease in head acceleration was observed*". A benefit from AB activity in a particular situation (143). Similarly 33 moderately physically active volunteers were recruited to investigate whether facial electromyography (EMG) recordings reflect the perception of effort and primary active lower limb muscle activity during incremental workload cycling. Their conclusion was that jaw clenching facial expression can be considered an important factor that determines the perception of effort in both males and females (144).

A brief abstract in 'Toxicon' talked of managing dementia patients with audible diurnal bruxism using bilateral injections of botulinum toxin type A to masseter and temporalis muscles. In the majority of the patients the treatment lasted 6 months. No secondary effects were reported. They concluded that it was an easy and efficient form of management and, in advanced dementia, an alternative to other medical or behavioural interventions (145).

A paper titled "Current treatments of bruxism" has a short sentence at the end of the conclusion:

"*Even more must be done to successfully treat awake bruxism, in which RCTs are still lacking*" (146).

The subject of the use of drugs in dentistry as a treatment option is one which arises now and again.

A case series paper looked at the management of 5 patients with Selective Serotonin Reuptake Inhibitor (SSRI) induced bruxism. These patients had either stopped their medication (SSRIs) or were on the verge of doing so because of the bruxism that it induced. SSRIs are the most widely prescribed group of medications worldwide for depression. All 5 patients were prescribed low doses of Quetiapine, which is frequently used elsewhere in psychiatric medicine. After a few days the

patients reported no bruxism and could return to or continue their SSRI medication without side effect (147).

In an extensive paper discussing all aspects of bruxism, the author discusses how the management of bruxism can be divided into 3 different approaches: dental occlusal, cognitive/behavioural and pharmacological. This has been previously described as the 'triple P' approach (137). He describes the dental occlusal approach as the most used, subdivided into non-reversible and reversible. Non-reversible methods are selective permanent dental occlusal adjustments, orthodontics and even prosthetics. He comments: "*it is not considered state of the art to perform an occlusal intervention as a management strategy for bruxism"*. He mentions that physiotherapy and jaw exercises are now commonly included in self-management packages for AB patients, noting that increasing the patients' awareness of the clenching/grinding activity may be beneficial as a cognitive-behavioural approach (14).

In a letter to the editor, a group of authors introduce a novel smartphone-based app called 'BruxApp'. They acknowledge the advancement in understanding of SB but note that this is not yet the case with AB as improved knowledge is limited by the difficulties of achieving a definite diagnosis in the clinical setting. This app is based on Ecological Momentary Assessment (EMA) methodology which enables an on-time report of the condition under study, for example jaw clenching, teeth contact or teeth grinding. Users receive alerts at random frequency during the day and give a yes/no response, by tapping on the specific display area, on eight main items. The app has a section with information on bruxism, in particular to inform the user about developing awareness of the behaviour and so reducing its frequency (148).

In "The clinical management of awake bruxism" the authors combined information from articles on AB with a review of cases to arrive at a treatment protocol for AB. Lack of patient awareness leading to underreporting is a significant issue, therefore clinicians need to look for clinical signs and symptoms. Then a discussion with the patient about the possibility of daytime bruxing activity being

the cause, whilst it may produce a negative, even defensive reaction at first, can gradually generate their awareness of their non-functional oral behaviours.

The other types of management referred to were:

1. Occlusal appliances, conceding that compliance can be a challenge with a daytime splint.
2. Psychosocial approaches: stress reduction, counselling, lifestyle changes, hypnotherapy, biofeedback and bringing a therapist into the team.
3. Medical treatments: muscle relaxing medications and botulinum toxins.

They conclude that identification and management of AB can be a challenge for clinicians. Sometimes once the patient becomes aware of the daytime teeth contact they are more ready to accept a daytime appliance (149).

A study evaluating the effects of listening to music on jaw muscle activity and awake bruxism, at first concluded that although the effect of music on the EMG activity of the masseter muscle during rest was significant, it seems to be of little clinical value. In spite of that, they later stated that Guided Music Listening (GML) may be a potential tool to decrease the intensity of tooth clenching episodes in individuals who indulge in awake bruxism (150).

A randomised controlled trial investigated the effect that reminder systems have on awake bruxist patients. 30 TMD patients were split into 3 groups. 1) received email reminders, 2) were advised to use sticky notes at home and at work, 3) control group received verbal instructions before the trial but no instructions during. The researchers concluded that their email based reminding system may potentially be an effective tool for the self-management of AB (151).

A study of 60 patients in a private dental clinic using a patented intraoral device called DIVA, all were aged 18 and over and diagnosed with bruxism, were evaluated pre-treatment, then after 7, 30 and 90 days. This device covers the occlusal, buccal and lingual surfaces of 4 posterior teeth

unilaterally, either upper or lower and contributed to pain relief in the majority of patients who used it (152).

Another study looked at the effect that music could have on awake bruxers suffering from TMD. While stressful music increased the muscular effort during awake bruxing episodes, relaxing music reduced it. Guided Music Listening (GML) therefore could be a promising and non-invasive component of a multimodal approach to managing AB (153).

2.3.10 2021 to 2023

The alternative ways of trying to manage AB have been many and varied. Varied forms of biofeedback appear and re-appear regularly. An intra-aural device is individually made for each patient from an impression. It intimately fits the ear canal when the jaw is relaxed, so feeds back to the patient a feeling of tightness during bruxism, so encouraging jaw relaxation. A group of 7 patients were tested with such a device. Two patients used them for more than 6 months and had relief of symptoms. One patient used it for 6 months with some relief of symptoms. The remaining patients handed the device back. The researchers concluded that while this type of device has great potential, the complications that arose need to be dealt with and some functions added to build higher patient awareness (154).

The use of the smartphone based application as an ecological momentary assessment of AB activity is increasing. 31 university students completed a study using a smartphone -based approach and the researchers concluded that it may be helpful over time to monitor AB, increase an individual's awareness of it and therefore increase their chances of managing it to reduce the activity (155).

In a case report on an adolescent with cerebral palsy and global developmental delay, his AB and SB were both managed using 4mm thick, soft upper and lower splints made from a silicone type material. It is noteworthy that part of the reason for treating him was the concern that his bruxism

provoked in his parents. There are other reports in the literature in a similar vein, where the patient's awake bruxism particularly induces concern or distress in carers (156).

A group of 14 female, chronic TMD sufferers were evaluated for the effects of a standardised first-line non-invasive approach (FL-A) using counselling and self-management strategies on pain, muscle tenderness and AB. Baseline data consisted of clinical assessment, EMG recording of the right masseter for 20 minutes, completion of Oral Behaviour Checklist (OBC), State-Trait Anxiety Inventory (STAI) and measurement of Pain Pressure Thresholds (PPT) at the superficial masseter and anterior temporalis muscles bilaterally. After 1 month the clinical assessment and the EMG recording were repeated along with questionnaires and PPT assessment. After a further 1 month another clinical assessment, questionnaires and PPT repeated with review and reinforcement of the FL-A. The authors conclusions were that an FL-A is effective in improving pain and reducing the intensity and frequency of AB episodes in women with chronic TMD myalgia. They suggest that, given its high impact, this technique should be prioritised in similar individuals and that general practitioners could implement it for similar patients (157).

In a series of 3 papers in the BDJ entitled "The dental demolition derby: bruxism and its impact" the whole bruxism scenario is reviewed, SB being given more attention than AB reflecting the situation in dental literature in general. In the second paper- part2: early management of bruxism the authors say, "*management is a long term process and there is no quick fix".* They stress that diagnosis and patient education are the core of management and 'primum non nocere' (first, do no harm) is paramount. They emphasise assessment of need of intervention and have a rating need scale of 'low', 'medium' or 'high'. The interventions for AB examined are:

1. Pharmacological – prescription of various medications that reduce central and peripheral drive to muscles or Botox injection directly into the muscle. However they indicate some pause for thought here as if we now consider bruxism a centrally driven issue, is local

application appropriate? Indeed we know that the effect of Botox wears off in 3-4 months. So they suggest it be considered a rescue treatment for patients with muscular pain.

2. Behavioural – such as cognitive behaviour therapy (CBT), hypnotherapy and biofeedback. Biofeedback in particular can be beneficial as it gives direct control to the patient.
3. Appliances – It would be unlikely to get patient co-operation in wearing a conventional occlusal splint during the day. So, 'Daytime habit modifiers' have been designed in the form of a small device, usually in the lower jaw, with an interference somewhere on an occlusal surface.

They conclude that no single approach works for all. Appliance therapy is probably the core of management in the area of prevention of tissue damage from AB (158). Vieira and colleagues looked at the effectiveness of biofeedback in managing individuals with AB in a systematic review of the literature. They concluded that there were insufficient studies in general on the management of AB and in particular insufficient studies of good quality examining biofeedback. They commented that no other review to date has attempted the same thing and that in addition researchers should not only look at reduced muscle activity as the main outcome but also look at pain, quality of life and disability for these patients (159). This is in agreement with current guidelines which recommend patient self-report and in particular the collection of data concurrent with the event (2). The conclusions from this study by Vieira and colleagues did not mention tooth damage as an outcome, highlighted the small number of studies involved, their overall low level of evidence and as will be discussed in this review, the time demand placed on patients in a biofeedback study is a negative factor regarding it's use. Therefore they could not fully support the use of biofeedback to reduce AB, a similar finding to this systematic review.

In general in the bruxism literature there is a paucity of good quality studies examining the management of AB and an absence of studies comparing forms of management.

2.3.11 Additional Literature Review from August 2022 to August 2023

Having written most of the study, a further review of the literature was carried out on 30th August 2023 using the same search strings as originally used in 2022 with the addition of some hand searches.

Clearly the volume of AB literature is increasing quite substantially. It is summarised under a number of headings.

GENERAL

The last few years has seen a marked increase in the volume of literature related to AB. A paper by Bracci and co-researchers discussed possible research routes for AB metrics with the implications of the updated bruxism definition (160).

A similar group of authors looked at Current Knowledge and Future Perspectives on Awake Bruxism Assessment (5). They drew attention to the fact that early data suggests that muscle bracing and simple teeth contact are the most commonly reported behaviours, whilst teeth clenching is much less frequently reported than was commonly believed. They stated that one of the concerns that emerged from the work of the recent expert consensus panel when contributing to the updated definitions of bruxism is that a summary of the available approaches to evaluate AB is missing. They considered that a combination of approaches, encompassing self-reported and instrumental evaluations, which is currently being defined in "Standardized Tool for the Assessment of Bruxism" (STAB), is likely to emerge as the best strategy to overcome the limitations of different approaches.

A study in Belgium examined the concept of "Bruxism as a new risk factor of musculoskeletal disorders?", with a secondary objective looking at the association between tooth wear and musculoskeletal disorders.

They concluded that bruxism and tooth wear were associated with musculoskeletal disorders,

suggesting that the body is a whole with each part playing its role as a link in the chain (161).

A very interesting study by Mungia and an extensive list of co-researchers entitled:

" Dental practitioner approaches to bruxism: Preliminary findings from the national dental practice-based research network" looked at dental practitioner assessment and treatment of bruxism. With responses from 397 practitioners, more than half treated one to three patients a month, most frequently offering an occlusal guard. Distressingly 46% made occlusal adjustments in an effort to manage the behaviour despite multiple recommendations in the literature advising against making irreversible changes in the treatment of bruxism (138).

A further finding from the study was that only 1% of practitioners offer "doing nothing" as a treatment option. The authors comment that current understanding is that negative consequences should outweigh positive consequences before management options should be instituted. The percentage figure above could indicate overtreatment.

These figures are consistent with the notion that no standardised approach exists and that future studies are needed (162).

A study that falls across a number of categories looks at "*Assessment of awake bruxism and oral mucosa indentation in adolescents"* concludes that there is a high frequency of AB in adolescents with teeth contacting and cheek indentation being the most frequent condition/behaviour observed and that the two phenomena were related (163).

PREVALENCE

Three studies deal with prevalence in three different populations.

The first are general dental patients attending a university clinic in the dental department of a regional hospital in Italy. 1424 patients completed the Oral Behaviours Checklist (OBC). Once

again light teeth contact, pressing, touching, or holding teeth together other than while eating 52.7% was more prevalent than awake clenching at 47.5% (6).

The second study looked at AB frequency and psychosocial factors in college preparatory students. In addition to using the OBC the researchers used ”BruxApp” for the EMA evaluation of AB activity.

Once again “teeth contact” followed by “mandible bracing” were the most frequent behaviours reported, while “teeth grinding” had the lowest prevalence throughout the evaluation period. This is a frequent finding in several recent studies. These oral behaviours were significantly correlated with psychosocial factors (164).

Possibly the most interesting of all three studies is the third one looking at “Prevalence and awareness of oral habits among adults in Riyadh, Saudi Arabia”

The most prevalent oral behaviour was “using teeth as a tool” (46.8%) but that was closely followed by “chewing ice” (43.6%). The authors say that while chewing ice may seem harmless it puts the teeth at risk for fractures, cracking and chipping.

Their conclusion is followed by a very interesting recommendation. They suggest that the best way to prevent oral habits is to embed it in all public services. They suggest that schools and universities should have awareness sessions about the prevention and adverse effects of oral habits. in addition they recommend that all preliminary, middle and high school students together with university students should be screened to pick up these oral habits and deal with them as early as possible (165).

This introduces a whole additional option into the range of ways for managing oral behaviours. One that so far, in the literature, has not been encountered.

The recent introduction of smartphone-based Ecological Momentary Assessment (EMA) has generated some interesting data on AB behaviours. A scoping review looks at these studies based

on data from young healthy adults. Their frequency based percentages very considerably. The results from seven of the studies reported a frequency of AB behaviours over 1 week varying between 28.3 and 40%. Another study using a different smartphone-based EMA approach via WhatsApp reported a frequency of 58.6%. It is interesting to note that once again teeth contact as opposed to teeth clenching was the most frequently reported behaviour across all studies. Report of teeth grinding in AB behaviours was almost entirely absent (166).

ASSESSMENT

It is broadly agreed that no consensus exists regarding the examination methods and the assessment criteria for AB. A group of 104 individuals, divided into study group and control group according to defined criteria, was studied using both EMG and EMA. The subjective assessment was conducted using EMA and an objective assessment, using EMG signals, was carried out at the same time. The authors consider this, to the best of their knowledge, to be the first study of its kind. Based on their findings they propose that three events/hour with a 20% MVC with a duration of $\geq$1 s as the cut-off EMG parameter for AB screening. they concede that further verification is needed before this could be applied in clinical practice (167).

The other study in this category is a literature review looking at portable and wearable devices for the assessment of SB and AB.

They found that substantial advances have been made in the area of portable/wearable devices and many parts have been miniaturised. Whilst the batteries have also been downsized, they are the biggest factor preventing further shrinking in the size of these devices.

They conclude by saying that while these devices can be put to good use with a high level of accuracy in assessing SB, there is not as yet a definite cut-off value for the assessment of AB. As we have seen in other studies (168).

EFFECTS OF AB

In a cross-sectional observational study, Pereira and Quaresma studied the changes that Hospital Healthcare Professionals (HHP) were subjected to during the Covid-19 pandemic. They aimed to evaluate the association between SB, AB and other parafunctional habits on the one hand and the levels of depression, anxiety and stress in these individuals after the Covid-19 pandemic. The Portuguese version of the OBC was used. There were 118 individuals.

They found a statistically significant association between a positive diagnosis of AB and levels of stress, anxiety and depression. Similarly with SB. The diagnosis of it being more prevalent when anxiety is occurring with greater frequency.

They conclude by advocating for the importance of the dentist's role in diagnosing these oral behaviours in order to establish information and preventions campaigns to minimise their effects.

There are echoes here of the conclusion in the paper about the prevalence of oral habits in adults in Saudi Arabia. In other words a role for public health authorities in the reduction of these damaging oral habits (169).

A group of clinicians in Germany reported in 2022 on what they regarded as the first known clinical case of a patient developing apical periodontitis due to bruxism in both lower first molars. Root canal therapy instrumentation was carried out without local anaesthetic on both teeth. After a period of intracanal medication with calcium hydroxide both root canal therapies were completed. All clinical details together with a full differential diagnosis are fully described in the paper (170).

Pulp death, requiring root canal therapy or exodontia can be added to the list of possible consequences from bruxism.

DIAGNOSING AB

Whilst diagnosing AB is not the same as managing AB, as we have seen in this literature review, the generation of awareness of AB in our patients is a significant start to the reduction of the oral behaviour. So diagnosis and management are very closely related.

The development of a standardised tool for the assessment of bruxism (STAB) is a significant development in research progress in AB. The lack of such an assessment tool has been a continual source of deficiencies in AB research as is frequently mentioned in studies related to bruxism in general but particularly AB.

STAB has been developed "*to provide a multidimensional evaluation of bruxism status, co- morbid conditions, aetiology and consequences."* The tool consists of 2 axes. Axis A deals with the evaluation of bruxism status and consequences. Axis B examines bruxism risk, aetiological factors and comorbid conditions. It is an extremely comprehensive tool probably more suited to research environments than clinical ones (171).

As STAB does not meet the "A4 principle" for a bruxism assessment tool, i.e. being Accurate (reliable and valid), Applicable (feasible), Affordable (cost-effective) and Accessible (suitable for everyday clinical use), the bruxism screener (BruxScreen) to be used in large scale research projects and in particular in general dental practices.

BruxScreen is divided into 2 parts, part 1 is a self-report questionnaire using some questions from the Oral Behaviours Checklist slightly modified (172). Part 2 is a clinical assessment form assessing the patient both extra-orally and intra-orally. The authors conclude that following pilot testing and the face validity assessment, this tool is now ready for the general dental setting (173).

MANAGEMENT AB

In a study entitled *"Common therapeutic approaches in sleep and awake bruxism — an overview"* the authors' aim "*was to present the pathophysiology, consequences, types and treatment methods of bruxism in order to increase readers' knowledge of this topic*". Following a discussion of aetiology, pathophysiology and diagnosis they list a number of options for bruxism therapy many of which largely deal with SB. There is a brief section talking about short-term medications, including the use of NSAIDs for pain relief, Tolperisone (e.g. Mydocalm) to reduce skeletal muscle tone and Hydroxyzine for anxiolytic and sedative treatment. They concede however that recent studies show there is insufficient evidence-based data regarding medications reducing SB or AB.

They finish by stressing that the importance of awareness campaigns and the encouragement of earlier check-ups must be underlined together with the broadening of medical professionals' knowledge of bruxism (174).

"Evidence on the management of bruxism using nonconventional treatment has not been previously addressed"

A scoping review on traditional medicine for bruxism analysed 16 studies. The overall quality of the studies was fair to poor and there were few RCTs. The authors concluded that traditional medicine has a place in managing bruxism and although there is only limited evidence, it is known that certain therapies help with stress reduction and therefore with muscle relaxation (175).

A study making a retrospective assessment of the clinical performance of the complete oral rehabilitation of 16 patients treated with implants and teeth supported veneered and non-veneered monolithic zirconia restorations with increased vertical dimension of occlusion (VDO), concluded that there was a high rate of survival of both implants and restorations. In the veneered group the predominant complication was minor chipping which only required polishing. In the non-veneered group the major complication was open contacts between the implant restorations and the adjacent

teeth (14.5%). Whilst all patients were given an occlusal splint on completion of treatment and were instructed to wear them during sleep. At the recall appointment only 7 patients out of the original 16 reported wearing the splint during sleep. All patients adapted completely to the new VDO without reporting any signs or symptoms of TMD throughout the follow up time. The increase in VDO ranged from 2 to 7mm (mean: 3.3 ± 1.6mm) measured in the anterior region with callipers.

An additional conclusion was that in bruxer patients when there is minimal tooth structure, connecting two adjacent restorations may be advised (176)

BOTOX TO MANAGE AB

The volume of studies and research into the management of bruxism using Botulinum toxin (BTX) continues to grow.

In a systematic review and meta-analysis of RCTs on the subject the authors carried out a systematic review that included RCTs, cohort and observational studies published between January 2020 and November 2022.

They suggest that the advantages of BTX outweigh its minimal side effects. In contrast to oral splints that require strict compliance, BTX exerts a continuous 24-hour effect. They conclude that BTX injections are effective for managing bruxism with the therapeutic effect observable at less than 1 month and lasting up to 24 weeks. There may also be the added benefit of the BTX treating hypertrophic facial muscles. They concede that while the BTX injections work earlier, traditional occlusal splints demonstrate more long-lasting benefits (177).

An updated systematic literature review looked at the use of Botulinum neurotoxin Type A in the management of primary bruxism in adults. They drew the following three conclusions:

1. All studies evaluated supported the effectiveness of BoNT-A injections in reducing primary bruxism symptoms.

2. It is possible to obtain a reduction of symptoms with doses lower than 25U applied exclusively in masseter muscles.
3. Randomized clinical trials comparing different manufacturers, doses, and application points are still needed to establish a protocol for the use of BoNT- A in the treatment of bruxism symptoms (178).

RELATIONSHIP BETWEEN BRUXISM, DENTAL IMPLANTS AND IMPLANT SUPPORTED PROSTHESES

A systematic review published in 2022 set out to study the relationship between bruxism, implant failure and implant-supported restorations. The studies included had to fulfill the following criteria:

Were RCTs, non-randomised control trials, retrospective studies and cohort studies.

Had relevant data on bruxism effects.

Minimum of 20 implants per study.

Follow-up data available for a minimum of 12 months

Delayed loading.

The authors concluded that bruxism is to be considered as a risk factor for dental implant failure. That further research is needed with clear and evident bruxism diagnosis and unified units of measurement (179).

Another systematic review and meta-analysis carried out in 2023 aimed to evaluate implant failure and marginal bone loss in patients presenting with probable bruxism compared to non-bruxers. There were 27 studies included in this review. Häggman-Henrikson and co-authors concede that although the diagnosis of probable bruxism in all studies was based on self-report together with clinical examination, once again, there was not a homogeneous set of criteria used. However they feel this is offset by the large number of primary studies used and therefore a reassuring number of implants included in the analysis. their main finding is that probable bruxers present a statistically significant higher risk of implant failure than non-bruxers. The clinical implication of this being that the assessment of bruxism needs to be included in the treatment planning stage of implant treatment (180).

RELATIONSHIP WITH TMD

The volume of literature on the relationship between TMD and bruxism, especially AB, has increased substantially in the last two or three years.

A systematic review and meta-analysis by Mortazavi and colleagues posed the question: "Is bruxism associated with temporomandibular joint disorders". The aim of the study was to examine and quantify the association between bruxism and temporomandibular joint disorders. The PRISMA flow diagram shows that they included 20 studies.

Although there are some studies showing a positive relationship between the two phenomena, different results have been obtained due to differing operational definitions, methodological differences, and varying diagnostic tools in different studies.

They concluded that bruxism is positively related to TMDs, the presence of bruxism increases the risk of developing TMDs in the future. Bruxism must be diagnosed early, the patient exhibiting the behaviour should be informed and in addition informed of the possible consequences if it is not managed (181).

A study by Beddis and Davies looks at relationships between tooth wear, bruxism and TMDs. They note that the prevalence of TMD in the general population is much higher than the incidence of a diagnosis of a TMD in general practice. This study starts in a general way but then seems to tilt towards SB and SB related issues. Amongst the points that they advise readers to consider in their conclusion, they state: bruxism is not an 'occlusal disease' nor is it caused by malocclusion; TMDs are not caused by the occlusion and there is no clear evidence for bruxism as a cause of TMD; a permanent change in the occlusion is not a primary management of TMD (182).

A study by Camara-Souza and co-workers aimed to assess AB frequency in patients with myofascial pain and temporomandibular joint (TMJ) pain and compare it to a group of pain-free individuals.

They had 84 participants, 54 in the TMD group and 30 non-TMD volunteers. AB frequency was obtained by EMA assessment with a dedicated smartphone application that sent sound alerts at random intervals during the day for 1 week. They observed that patients with TMD-related pain have a significantly higher AB frequency and that the AB activity was mainly jaw bracing. Managing this could be an important step to prevent TMD onset (183).

Bearing in mind the variation in conclusions in previous studies regarding the AB/TMD relationship a retrospective study looked at AB assessment and TMD management in TMD patients referred to tertiary care. The authors found that in spite of various treatment modalities, only half of the patients experienced improvement in their symptoms. Their principle conclusion was that a standardised assessment method encompassing all contributing factors is needed for both clinical and research purposes. They suggested that the recently completed STAB and the shorter BruxScreen may be feasible (184).

A cross sectional study by Silva and co-researchers aimed to evaluate the association between headache, myofascial TMD and AB. The authors state that to their knowledge this is the first study to evaluate these three conditions together and their suggestion was that they might have a comorbid relationship. The sample consisted of 307 individuals assessed for myofascial TMD, of whom 269 (68.4%) were positively diagnosed for this condition. Moreover, 305 patients were assessed for headache and 267 were assessed for AB, of whom 221 (72.5%) and 180 (67.4%) respectively self-reported having these conditions.

They concluded that individuals who self-reported headaches in the past 6 months were more likely to have AB and myofascial TMD and that individuals with AB and myofascial TMD were more likely to present with headaches. Indicating association between these comorbidities (185).

There are an increasing number of studies looking at the relationship of bruxism behaviours with pain and conditions in other parts of the body.

Agha-Hosseini and co-researchers looked at “Treating Parafunctional Habits for Alleviating Temporomandibular Disorder and Lower Back Pain: A Phase II Clinical Trial”.

A total of 136 patients successfully completed the two-month study course, including 92 females and 44 males. They concluded that parafunctional habits may be a cause of both TMD and back pain but they conceded that larger patient samples are needed to confirm their findings (186).

AB AND SB ASSOCIATION

A study by Chattrattrai and colleagues looking at the association between AB and SB tested 2 hypotheses. (1) that individuals engaging in SB also engage in AB and (2) that SB and AB are associated with different subtypes of activity. 122 cases were recruited from patients seeking treatment at the New York University College of Dentistry (NYUCD) and 46 controls from other NYUCD clinics and acquaintances. Their results show that tooth grinding was the main characteristic of SB and tooth clenching the main characteristic of AB. They concluded that SB and AB do not typically characterise in the same individuals (187). This is in sharp contrast with Winocur and co-researchers who found that individuals who exhibit AB symptoms are 5 to 7 times more likely to show SB symptoms and vice versa (188), (189).

CHAPTER 3. METHODS

3.1 PROTOCOL & REGISTRATION

The protocol for this systematic review was written and has been registered with PROSPERO.

The registration number is: CRD42022351309

This study was conducted in accordance with the PRISMA methodology (190), (191).

The title is: An investigation into the management of awake bruxism: a systematic review.

3.2 DATA SOURCES

The following data bases were searched:

- Medline via Ovid
- Embase via Ovid
- Scopus
- LILACS
- CINAHL
- OpenGrey
- Trip Medical database

In addition Google was searched.
All initial searches were done on 30th August 2022. No hand searches were conducted at that time.

In the later literature search on 30th August 2023 the same data bases were searched, hand searches were conducted in addition. All searches were conducted looking for studies in English.

3.3 SEARCH STRATEGY

The search strategy was generated around the 3 words: awake, bruxism, management.
For each word the most frequently used, relevant synonyms were sought in the dental literature:

- Awake – diurnal, daytime
- Bruxism – clenching, parafunction, oral behaviour, oral habit
- Management – treatment, therapy, cure, intervention, surgery

The search capacity was enhanced by the following:
Shortening behaviour to behavio* to capture different spellings and word ending.
Adding * to habit – habit* also captured the plural
Therapy was shortened to therap* to capture different word endings.
See Appendix 2 for details of all search strategies.
All literature retrieved from the searches was retained in EndNote20 (192).

3.4 COVIDENCE

3.4.1: IMPORT REFERENCES

Once all references had been collected in EndNote20 (Thompson Reuters, Philadelphia, PA., U.S.A.) they were imported into Covidence (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia 2023). Covidence is a web-based collaboration software platform that streamlines the production of systematic and other literature reviews.

3.4.2: INCLUSION CRITERIA

In collaboration with other researchers, the inclusion criteria were set. As the literature concerning awake bruxism is comparatively small, the following were included in the initial searches:

- Randomised controlled trials

- Non-randomised controlled trials
- Reports or trials involving teenagers or adults
- Case series reports
- Papers written in English

3.4.3: EXCLUSION CRITERIA

In order to keep the volume of literature to the maximum and spread the net as widely as possible, there were simply two exclusion criteria:

- Studies, reports or information solely about sleep bruxism.
- Studies about anyone 12 years old or younger.
- Papers written in languages other than English.

3.4.4: TITLE AND ABSTRACT SCREENING

Once duplicate references had been removed in Covidence, 2 researchers independently screened all the balance filtering them on a yes/no/maybe basis. If conflicts arose, the researchers conferred on a regular basis to resolve them. A third researcher (B.H.-H.) had been set to resolve any unresolvable conflicts.

3.4.5: FULL TEXT REVIEW

Prior to commencing this review attempts were made by two researchers (D.G. & B.H.-H.) to retrieve the full texts to all references.

Before starting this process, decision options had been entered into Covidence with specified reasons for texts being excluded. If the no option was chosen for a given text, one of these reasons had to be specified. Two researchers (A.L.& D.G.) then went through each text, independently, allocating each one to either included or excluded. This process gave rise to a number of conflicts requiring consensus. A third researcher (B.H.-H.) resolved these consensus decisions, either independently or by appointing one of the two original researchers to resolve the conflict.

3.4.6: DATA EXTRACTION

This was done in Covidence and the extracted data is presented in Table 2. The data is laid out in 7 columns:

Author, year, study setting and country
Study design, aim
Study sample with mean age (SD) range
Intervention
Outcomes
Authors' conclusion
Comments

Data extraction was done by B.H.-H. and D. G.. Final tabulation designed by B.H.-H. & D.G. It was done independently with no disagreements.

3.5: QUALITY/RISK OF BIAS ASSESSMENT

Assessment of quality/risk of bias in the included studies was carried out using the Newcastle-

Ottawa scale (192) for case control and for cohort studies with the following criteria:

Selection: S1: Definition cases
S2: Representativeness cases
S3: Selection controls
S4: Definition controls

Comparability: C1: Age
C2: Other factors

and for case control studies:
Exposure: E1: Assessment
E2: Same method cases and controls
E3: Nonresponse rate

or for cohort studies:
Outcome O1: Assessment
O2: Length follow-up
O3: Follow-up rate

A star system is used to rate the studies, the more stars the better.

For randomised control trials, the RoB 2 scale was used (193). Each study is assessed for bias in five domains:

Selection, Performance, Attrition, Detection and Reporting with three response options: Low,

Unsure or High. An overall risk of bias for a study usually corresponds to the worst risk in any of

the domains. However, a study with multiple Unsure responses might be judged as high risk of bias overall.

The quality/risk of bias process was carried out by two researchers (B.H-H. & D.G.) working independently

CHAPTER 4: RESULTS

Table 1. Data sources searched and results retrieved

DATA SOURCES	RESULTS RETRIEVED
Scopus	2828
Trip medical	806
CINAHL	674
Embase	650
Medline	612
Google	62
LILACS	7
OpenGrey	1

The search of Scopus data base revealed 2828 results, Trip Medical 806, CINAHL 674, Embase 650, Medline 612, Google 62, LILACS 7 and OpenGrey 1 result.

Of these 1537 were removed as duplicates, leaving 4420 for title and abstract screening.

Following the completion of that process by two independent researchers (A.L. & D.G.), 4207 were excluded with 213 left for full text retrieval.

Of those studies the full text of 3 were unable to be retrieved.

210 moved on for full text assessment by two independent researchers (A.L. & D.G.).

The 9 studies left at the conclusion of this process are those being reviewed.

This selection process is illustrated in Figure 1 . the PRISMA Flowdiagram.

Fig. 1

PRISMA Flow Diagram

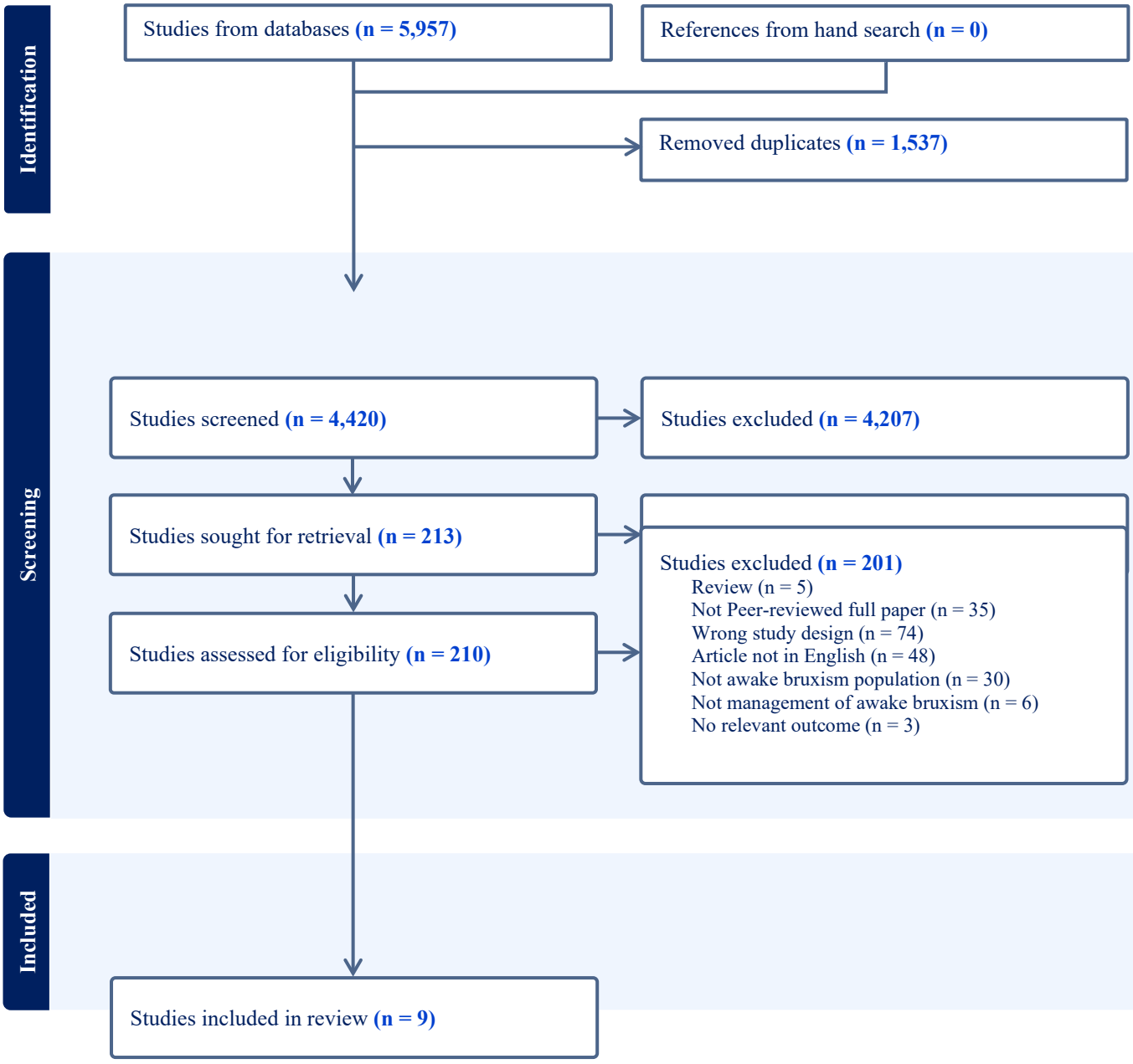


Table 2. Main reason for exclusion at full text level (n = 201).

First Author, Year	Main reason for exclusion
Alves 2009, Campos Ortega 1988, Garay 1975	Article not found
Akabori 1984, Alcolea 2019, Alkumru 1985, Alonso-Navarro 2011, Arduino 1984, Buchner 1968, Chavarry Angulo 1973, Chikhani 2003, Gomesde 2012, Demner 1986, Doğu 2009, Echevarría Muro 1965a, Echeverria Muro 1965b, Fischer 2019, Fraccari 1988, Fröhlich 1966, Gastone 1983, Jimenez-Castellanos Ballesteros 1991, Klewansky 1974, Kobayashi 1974, Korn 2005, Kotran 1981, Liem 2022, Mutschelknauss 1967, Orlova 2019, Pascual Hernandez 1988a, Pascual Hernandez 1988b, Permann 1987, Popov 1971, Popov 1987, Pourre 1985, Pourre 1986, Rateitschak 1966, Ring 1973, Romoli 2003, Spirgi 1970, Spirgi 1971, Su 2010, Tamdemir 2021, Teich 1979, Thom 1990, van der Meulen 2000, van der Zaag 2000, Visscher 2000, Wang 1998, Yin 2004, Zhulev 1976, Zielinsky 1988.	Article not in English
de Lima 2021, Haggiag 2020, Lopes de Castro Bastos 2018	No relevant outcome
Ayer 1973, Ayer 1976, Baldini 2015, Cahlin 2019, Casas 1982, Cornellier 1982, Cruz-Reyes 2010, Dalewski 2015, Dalewski 2021, Diracoglu 2021, Gao 2019, Gholampour 2019, Grozev 1999, Guillot 2021, Heller 1975, Jardini 2006, Maeda-Iino 2020, Mkhitaryan 2020, Narita 2009, Ommerborn 2011, Peterson 1993, Rajpurohit 2010, Redaelli 2011, Saito-Murakami 2020, Sullivan 2001, Treacy 1999, Trindade 2015, Yazici 2020, Yurttutan 2019, Yustin 1993	Not awake bruxism population
Amsterdam 1992, Dias 2021, Emodi-Perlman 2021, Kef 2021, Pereira 2021, Wieselman-Penkner 2001	Not management of awake bruxism
Yurttutan 2019, Ak 2009, Allen 2006, Bassett 2017a, Bassett 2017b, Chong 2007, Consumer reports on health 2022, Dull 2013, Goldstein 2012, Gunepin 2011, Hamilton 1986, Harnick 2000, Kishi 2007, Kucuk 2013, Malcmacher 2015, Malcmacher 2017, Nassif 1999, Orlova 2018, Patel 2022, Piekartz 2009, Piekartz 2022, Prater 2010, Quinn 2000, Rechmann 2018, Santos Miotto De Amorim 2015, Scharer 1974, Solberg 1973, Stein 1998, Thompson 1994, Valentin 1976, van Waas 2001, Van Zandijcke 1990, Velon 2015, Young 2009, Yurttutan 2018, Yurttutan 2019.	Not Peer-reviewed full paper
Begum 2019, Christensen 2000, James 2009, Lobbezoo 2018, Shatkin 1992	Review
Ackerman 1966, Attanasio 1997, Attanasio 2000, Ayer 1975, Benk 2004, Bidaki 2022, Blanchet 2010, Blount 1982, Boxley 2017, Bracci 2022, Brown 1999, Brown 2022, Cannistraci 1976, Cannistraci 1987, Cherasia 1986, Dahl 1987, DuPont Jr 2006, Ellement 2021, Evans 2011, Gittelson 2005, Goldstein 2017a, Goldstein 2017b, Gouw 2017, Graf 1969, Greenwald 1968, Guaita 2016, Guevara 1998, Gurusidheshwar 2004, Gutman 1975, Heller 1973, Hennessy 2022, Ilovar 2014, Ingersoll 1952, Kaner 1952, Keith 1978, Kowacs 2021, Krattenmaker 2017, Kumar 2018, Kwon 2019, Lang 2013, Leib 1996, Leung 1991, Lobbezoo 2008, Malcmacher 2013, Mathew 2020, Meklas 1971, Muñoz Lora 2019, Myers 1990, Nash 2004, Nissani 2000, Okeson 1983, Ondo 2011, Palumbo 2007, Pina-Escudero 2021, Quinn 1995, Rateitschak 1971, Rosen 1981, Rubeling Jr 1979, Rudrud 1981, Sayers 1986, Sebregts 2020, See 2003, Shepherd 1971, Solberg 1972, Sugarman 1970, Sumner 3rd 1949, Tan 2000, Thayer 2022, Uthai 2021, Vavrina 2020, Yağci 2020, Yi 2013, Yüce 2013, Zeldow 1976.	Wrong study design (e.g. review article, case report)

4.1: RESULTS OF INDIVIDUAL STUDIES

Rosenbaum and Ayllon 1981 (111) examined 4 patients all of whom, on interview, reported different forms of awake bruxism. They were recruited either in response to an advertisement in a school newspaper or referred by their dentists. Treatment was split into three phases varying according to each individuals' habit. Treatment 1 habit reversal, 2 relaxation and stress management, 3 relaxation (2). They concluded that the habit reversal technique can be effective in decreasing and/or eliminating bruxism. The decreases were immediate, maintained over 6 and 12 months and effective regardless of whether the pretreatment frequency of the problem was high.

Manns and colleagues (110) study involved 33 patients divided into 2 groups: group 1 less than 1 year of evolution of symptoms, group 2 more than 1 year of evolution of symptoms. Audiostimulation and EMG biofeedback therapy was applied for 14 sessions, 5 per week, each session split into 15 minutes. First Audiostimulation in both ears, then EMG biofeedback in both ears, then Audiostimulation in one ear EMG biofeedback in the other. The results show most symptoms decreased around the 8th session with the last session showing complete absence of the initial symptoms except mild left masseter tenderness. They conclude that this treatment can be complemented with night guards and/or dental occlusal adjustment.

Watanabe and co-workers (15) study had 22 volunteers with mild to moderate masticatory muscle pain and daytime clenching behaviour, evenly split between biofeedback group and control group. The study ran for 4 days. Day 1 was a pretesting session to determine the EMG biofeedback threshold for each individual. Days 2 and 3 audio feedback sessions. Day 4 EMG recording without biofeedback. Four subjects in the biofeedback group had significant increases in parafunctional events on day 2, in spite of biofeedback training. They mentioned that they wanted to test how it worked. On day 3 this number decreased. The researchers thought that although there was a significant difference in both groups on days 3 and 4, it was impossible to confirm whether such an affect lasts longer.

Zandifar and fellow researchers (147) presented a case series of 5 patients all of whom developed AB from being given a Selective Serotonin Reuptake Inhibitor (SSRI) medication for Major Depressive Disorder (MDD). For three of these patients their condition improved after 5 days. For one patient it took 10 days and for the fifth patient it took 3 weeks. In all cases their condition

improved such that they could continue the SSRI medication. The authors concluded that low dose Quetiapine can improve bruxism which develops as a result of SSRI medication, which leads to the patient continuing treatment with the SSRI.

Cioffi and colleagues (150) looked at the effect of Guided Music Listening (GML) on 21 volunteers split into a High Parafunctional (HP) group and a Low Parafunctional (LP) group. The experimental phase composed of 4 tasks of 20 minute duration each during which the EMG activity of the right masseter muscle was recorded. One of the tasks was reading a gossip magazine (control task). The between group and within group differences were statistically significant, however as the values were below 1% of Maximum Voluntary Contraction (MVC) they felt the clinical relevance to be limited. They concluded that GML may be a potential tool to decrease the intensity of parafunctional tooth-clenching episodes in individuals with awake bruxism.

Takeuchi-Sato and co-workers (151) evaluated the effectiveness of an email based recording and reminding system for limiting daytime non-functional tooth contact (nFTC) in patients with TMD. 30 patients were randomly assigned to one of 3 groups: Cognitive Behaviour Therapy (CBT) with an email-based recording and reminding system for 20 days (eCBT): CBT with a sticky note reminder for 20 days (sCBT): a control group who were given simple verbal instructions before the experimental period. Even though the rate of 'no reply' responses for 4,320 emails was 66% they concluded that their email based recording and reminding system may be a potentially effective tool for managing AB.

Imbriglio and researchers (153) also looked at GML. To determine whether it modulates masticatory muscle activity and AB in subjects with chronic painful muscular temporomandibular disorders (TMD). They recruited 14 women with chronic TMD from patients seeking consultation at the Faculty of Dentistry for the mTMD group and 15 pain-free women from either the local community or friend matching as a control group. The EMG activity of the right masseter muscle was recorded with a wireless EMG device during 4 different periods. 3 periods were different music blocks and the 4th period was a non-music control (pink noise) block. They found that in contrast to their previous study (150), GML did not affect masseter activity in the control group during AB episodes, whereas it did in the experimental group. As there were only female subjects in the study, no conclusions could be drawn about men with TMD. They conclude that GML could be a promising, non-invasive component of a multimodal approach to the management of TMD and

hence AB.

Pfeiffer and colleagues (154) looked at biofeedback via an intra-aural device to treat bruxism. Seven female patients were recruited. Impressions were taken of their ear canals. The wearing protocol was 3 hours/day once a day for days 1 to 3, two wearing times of 4 hours each for days 4 to 7, all day (daytime) in the second week then also at night from the third week onward. Five patients returned their devices within the eight week testing period. Two patients wore theirs for seven and eight months each. One patient showed some relief of symptoms after three months and more after six months. the other reported a lower intensity of headaches and the feeling of clenching her teeth less. It was concluded that intra-aural devices have great potential for managing bruxism but some improvements are needed. The manufacturer withdrew the device from the market a few months later. At no point during the study did the authors show any justification for the use of such a device for the reduction of awake bruxism activity (154).

Donnarumma and co-workers (157) aimed to evaluate the effect of a standardised first-line noninvasive approach (FL-A) on pain, masticatory muscle tenderness and AB in women with chronic TMD (mTMD) (194). Women were recruited who presented for a TMD consultation. The final experimental group consisted of 14 women all of whom completed each component of the study.

In the discussion the authors discuss the fact that there was no control group. They felt that as these women all presented requesting pain management a control group would have been ethically questionable.

EMG recordings of the right masseter muscle were recorded at 2 time points, T0 at baseline and T1 after 1 month. The FL-A protocol consisted of patient education, which included pronouncing the letter “N” several times demonstrating the ideal space between mandibular and maxillary teeth when the jaw is at rest. Then in addition a comprehensive home-exercise regimen . The results show that all outcomes were consistent and clearly indicated that FL-A was effective in improving clinically relevant outcomes in the short term in patients with chronic mTMD. They also concluded that FL-A contributed to reducing both the intensity and frequency of AB episodes. In highlights at the end of the paper they state that FL-A could be implemented by general practitioners at least in the short term.

A summary of extracted data for the included studies is shown in Table 3.

Table 3: Summary of extracted data for the included studies (n=9)

First author Year Study setting Country	Study design Aim	Study sample Mean age (SD) range	Intervention(s)	Outcomes	Authors' conclusion	Comments
Cioffi 2018 University clinic Canada	Case-control study To evaluate the effects of guided music listening (GML) on masticatory muscles and on the amplitude of wake-time tooth clenching in individuals with higher vs lower frequency of clenching episodes.	Pain-free university students HP = High parafunction OBC-6 ≥9 10 (8 women) 21.4 yrs. (3.0) LP = Low parafunction OBC-6 ≤3 11 (9 women) 22.6 yrs. (2.9)	Four sessions: 1. Relaxing music 2. Stressful music 3. Favourite music 4. Control (reading)	<u>Rest EMG masseter:</u> Highest stress task (HP+LP) P<.001 Lowest: favourite music (LP), relaxing music (HP) both P<.001). <u>EMG clenching:</u> Lower favourite/stress music compared to relaxing music (HP) P<0.05 ; lower during stress music than reading (LP) P=.001) <u>Clenching episodes:</u> NS frequency or duration	GML modulates masticatory muscle activity. The response to GML depends on the frequency of clenching and the type of music.	Intervention similar to Imbriglio 2020
Donnarumma 2022 University clinic Italy	Descriptive cohort study To evaluate the short-term effects of a standardized first-line noninvasive approach in women with chronic TMD myalgia and to test whether patients' trait anxiety predicted response to treatment.	mTMD patients 14: 33.8 yrs. (11.1) 22-55 yrs.	Patient education, self-monitoring, avoiding oral behaviours prevention.	Masseter EMG activity reduced 30% (all P<.001). After 1 month: <u>EMG total MVC</u> decreased: mean (SEM) 1.51% (0.29) vs 0.98% (0.29); contrast estimate: 0.50% (0.05) 95% CI: 0.44-0.62; P<.001. <u>EMG bruxism MVC</u> decreased: mean (SEM): 28.26% (2.43) vs 20.32% (2.60) MVC; contrast estimate: 8.04% (1.42) MVC; 95% CI: 5.25 to 10.84; P<.001. <u>Clenching episodes</u> median (IQR): frequency decreased: 23 (31.2) vs 9 (17.5); P=.024; duration NS.	In the short term, FL-A reduces facial pain, masticatory muscle tenderness, and awake bruxism in women with chronic mTMD with low disability. A conservative management strategy should be prioritized for the initial management of these patients.	
Imbriglio 2020	Case control study	mTMD patients 14 women:	Four GML sessions: 1. Relaxing music 2. Stressful music	<u>Rest EMG masseter (%MVC)</u> mean (95% CI) affected in both groups compared to pink noise all	In subjects with chronic mTMD, relaxing music and the individual's	

University clinic Canada	To determine whether GML – a music intervention based on models of mood mediation and attention modulation – modulates masticatory muscle activity and awake bruxism in subjects with chronic painful muscular TMD.	median 39.5 yrs. (IQR 24.3) Controls 15 women: median 30.0 yrs (IQR 3.5)	3. Favourite music, 4. Control (pink noise)	P<.001: mTMD: 2.2 (1.6-2.8); controls: 1.1 (0.5-1.7); - increased by stressful music: [contrast estimate (95% CI); mTMD: +0.8 (0.7-0.8); controls: +0.3 (0.3-0.4); - decreased by relaxing music: mTMD: −0.4 (−0.5 - −0.4); controls: −0.3 (−0.4 - −0.3); - decreased by favourite music: mTMD: −0.5 (−0.6 to −0.5); controls: −0.5 (−0.5 to −0.4) EMG bruxism affected by group interaction, all P<.001. mTMD, compared to pink noise: 23.8 (16.0-31.6); [contrast estimate (95% CI): increased by stressful music +10.2 (8.6-11.8), decreased by relaxing −6.2 (−8.1- −4.3) and favourite music −10.2 (−12.2-−9.1) No effects in control group, P >.05. No effects for duration/frequency awake bruxism in either group.	favourite music decreased the muscular effort during spontaneous awake bruxism episodes by 26% and 44% (relative changes), respectively. In contrast, stressful music increases it by about 43%. Because of its positive effects on awake bruxism, GML with selected music could be a promising and non-invasive component of a multimodal approach for the management of chronic mTMD.	
Manns 1981 University clinic Chile	Descriptive cohort study Demonstrate the effectiveness of combined Audiostimulation and EMG biofeedback in the treatment of bruxism and myofascial pain dysfunction syndrome	TMD patients with bruxism 33 (26 women) 35 yrs., range 16-55 Group I: <1 year symptoms n=14 Group II: >1 year symptoms n=19	Audiostimulation combined with EMG biofeedback	Significant reduction in symptoms No difference between groups Rest EMG masseter decreased	We can conclude that the combination of Audiostimulation and EMG biofeedback is an effective therapeutic method for reducing symptoms in each patient group. These did not show any significant differences when compared at the end of treatment. This	Unclear reporting of the EMG data

					means that the efficacy of this therapy is independent of the evolution of the syndrome.	
Pfeiffer 2021 University clinic Germany	Case series To provide first clinical evidence that in-ear devices have a positive impact on relieving bruxism in patients.	TMD patients with bruxism 7 women Median 47.3 yrs., 23-64 yrs.	Personalized Cerezen in-ear device worn for increasing hours/day. Biofeed-back through pressure on ear-canal during closed jaw position.	Frequency of grinding reduced in some patients but 5 of 7 discontinued treatment.	Despite the limited number of participants, the study reflects a potential of Intra-aural devices as effective biofeedback devices in treating bruxism	Large drop-out and no control group
Rosenbaum 1981 University clinic United States	Case series To extend the generality of habit-reversal to the problem of bruxism.	Individuals with bruxism 4 clients (2 women) 23-42 yrs.	Habit reversal by individual management	Bruxism reduced	The results of this study indicate that the habit-reversal technique (Azrin and Nunn, 1973, 1977) can be effective in decreasing and/or eliminating bruxism.	
Takeuchi-Sato 2020 University clinic Japan	Randomised controlled trial To evaluate the effectiveness of an email-based recording and reminding system for limiting daytime non-functional tooth contact (nFTC) in patients with TMDs.	TMD patients 30 (17 women) 30.7 yrs. (8.7) e-CBT: 10 (7 women) 31.3 yrs. (10.6) s-CBT: 10 (5 women) 28.9 yrs. (8.2) controls: 10 (5 women) 32.1 yrs. (2.4)	1. e-mail-based CBT 2. CBT with sticky note reminders (sCBT) 3. Controls: Instructed to keep teeth apart when noticing non-functional contact.	<u>Freq nFTC:</u> Baseline (mean 95%CI) NS between groups p=0.33 1. eCBT: 45.3 (36.1, 54.4); 2. sCBT: 44.1 (35.0, 53.1); 3. Ctrl: 44.4 (36.5, 52.3). After treatment: decreased e-CBT and s-CBT P<.001; lower in e-CBT than s-CBT/control groups P<.001; 1. eCBT: 16.5 (9.76, 23.3); 2. sCBT: 28.3 (22.0, 34.5); 3. Ctrl: 35.7 [29.4, 42.0]	The present findings suggest that our email-based recording and reminding system may have the potential to effectively control daytime nFTC and could be an effective strategy for the management of TMDs	
Watanabe 2011 University clinic	Randomised controlled trial Electromyogram (EMG) biofeedback	Volunteers with pain/stiffness + daytime clenching 22 (11 women)	BF: hearing-aid-shaped EMG recording/ biofeedback apparatus (temporal	Number clenching events: Mean (SD) Day 1: BF 4.6 (2.5), control 4.6 (0.9) Day 4: BF 2.4 (1.7), control 4.4 (1.7);		

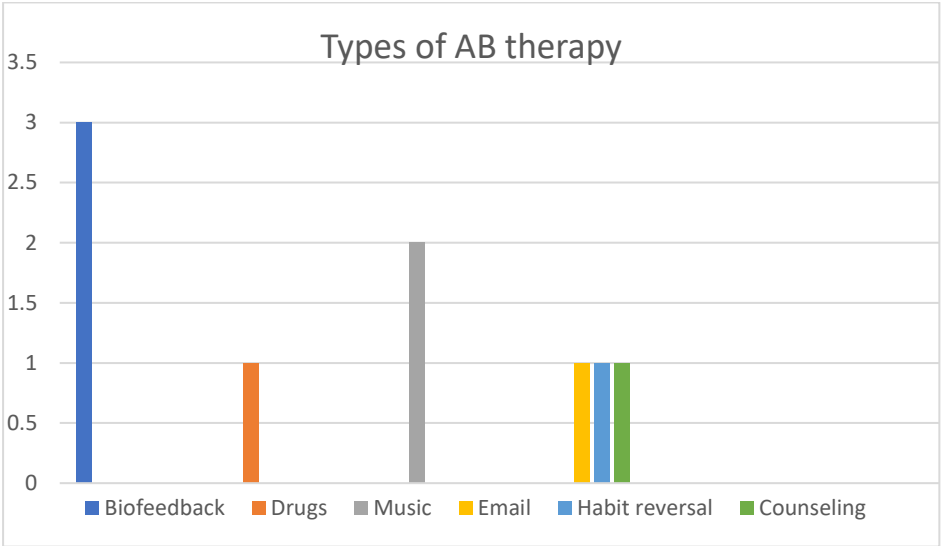
Japan	training was performed to ascertain its effect on the regulation of daytime clenching behaviour	30.9 yrs. (5.6): 10 Biofeedback (BF) 10 control (2 excluded)	muscle) 4 days, 5 hrs/day Days 2-3, BF group received clenching alert sound	decreased BF group P<0.05 NS control group		
Zandifar 2018 Hospital clinic Iran	Case series To find out from 5 case studies, if low-dose Quetiapine manages the bruxism induced by administration of Selective Serotonin Reuptake Inhibitors (SSRIs).	Patients with bruxism taking SSRI's 5 (4 women) median 28 yrs. (18-45 yrs.)	25-50 mg Quetiapine daily	Qualitative report of improvement in all 5 patients	Based on the results of the present study, low-dose quetiapine can improve bruxism and mandibular dystonia, which are side effects of SSRIs.	

A summary and chart of the types of AB therapy in the included studies is shown in Fig.2.

Fig.2

Types of AB therapy in included studies

1.	Biofeedback Manns Watanabe Pfeiffer	3
2.	Drug therapy Zandifar	1
3.	Music Cioffi Imbriglio	2
4.	Email reminders Takeuchi-Sato	1
5.	Habit-reversal Rosenbaum	1
6.	Counselling and self-management Donnarumma	1



Primary motivating issue in the included studies is shown in Fig 3

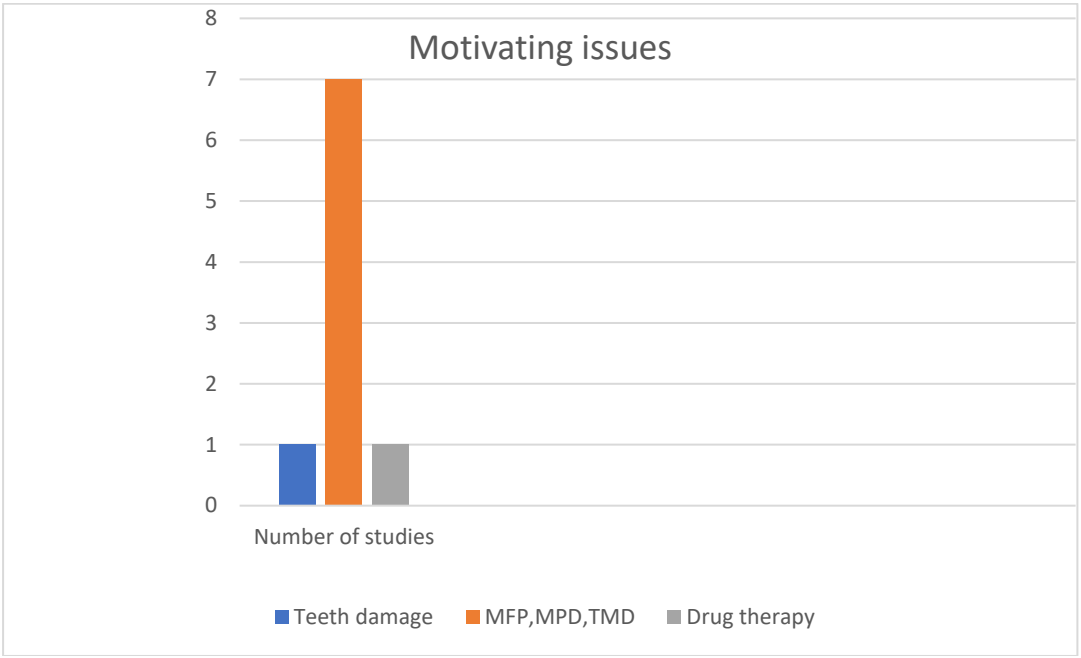
This summarises the factor, issue or possibly pathology that was the primary motivating factor for the authors to initiate the study.

The summary shows that the issue of MFP, MPD or TMD is far more prevalent, in these studies, than the issues of teeth damage or drug therapy

Fig. 3

Primary motivating issue for included studies

A. Teeth damage Rosenbaum	1
B. MFP or MPD or TMD Manns Watanabe Cioffi Takeuchi-Sato Imbriglio Pfeiffer Donnarumma	7
C. Drug therapy	1



4.2 QUALITY/RISK OF BIAS ASSESSMENT

In this study two scales have been used for quality/risk of bias assessment according to whichever is appropriate for the relevant study.

The Newcastle-Ottawa scale for non-randomised (case-control or cohort) studies.

Table 4. Risk of bias assessment of included case-control studies using the Newcastle-Ottawa Scale (n=5).

The Newcastle-Ottawa scale has a star rating. The more stars the better.

First author Year	Selection				Comparability		Exposure			Total
	S1	S2	S3	S4	C1	C2	E1	E2	E3	
Cioffi 2018	★		★	★	★			★		**5**
Imbriglio 2020	★		★		★			★	★	**5**
Pfeiffer 2021*	★									**1**
Rosenbaum 1981*										**0**
Zandifar 2018*										**0**

S1: Definition cases; S2: Representativeness cases; S3: Selection controls; S4: Definition controls. C1: Age; C2: Other factors. E1: Assessment; E2: Same method cases and controls; E3: Nonresponse rate.

*Please note that per the definitions of the criteria in the Newcastle-Ottawa scale studies without a control group cannot achieve scores for items S3, S4, C1, C2, E2 and E3.

Table 5. Risk of bias assessment of included cohort studies with the Newcastle-Ottawa Scale for cohort studies (n=2)

First author Year	Selection				Comparability		Outcome			Total ★
	S1	S2	S3	S4	C1	C2	O1	O2	O3	
Donnarumma 2022	★	*NA*	★	★	*NA*	*NA*	★	★	★	**6**
Manns 1981	★	*NA*	★	★	*NA*	*NA*		★	★	**5**

S1: Representativeness cohort; S2: Selection non-exposed cohort; S3: Ascertainment of exposure; S4: Outcome not present at start. C1: Age; C2: Other factors. O1: Assessment; O2: Length follow-up; O3: Follow-up rate. Note, as per definitions of the criteria for the Newcastle-Ottawa Scale, scores for item S2, C1 and C2 are not applicable (NA) since there the studies included did not involve non-exposed control groups.

Newcastle-Ottawa scale ranking

Good	3 or 4 stars in selection AND
	1 or 2 stars in comparability AND
	2 or 3 stars in outcome/exposure
Fair	2 stars in selection AND
	1 or 2 stars in comparability AND
	2 or 3 stars in exposure
Poor	0 or 1 star in selection OR
	0 stars in comparability OR
	0 or 1 star in exposure

Stars Totals rating: 0-2 : Poor, 3-5 : Fair, 6-9 : Good

Table 5 is similar to table 4 but shows the rating for cohort studies in the group. The difference between the two is that case-control studies are examined for exposure whereas cohort studies are examined for outcome.

Table 6. Risk of bias assessment of included randomized controlled trials studies with RoB 2 (n=2)

First author Year	Selection bias	Performance bias	Attrition bias	Detection bias	Reporting bias	Total
Takeuchi-Sato 2020	Low	Low	High	Unsure	Unsure	High
Watanabe 2011	Unsure	Unsure	Unsure	Unsure	Unsure	High

The third table in this group is Table 5. This shows quality/risk of bias assessment for randomised control trials rated according to the RoB 2 scale. In this scale the possible ratings are low, medium and high with low being the best and high the worst.

Table 7. Summary of risk of bias assessment for all included studies (n=9)

SCALE				
NEWCASTLE OTTAWA SCALE	SCORE	GOOD 6 – 9	MEDIAN 3 – 5	POOR 0 - 2
	Case-control Studies		Cioffi Imbriglio	Pfeiffer Rosenbaum Zandifar
	Cohort Studies	Donnarumma	Manns	
RoB 2 SCALE		LOW	SOME CONCERN	HIGH
				Takeuchi-Sato
				Watanabe

Table 7 groups the Newcastle/Ottawa and RoB2 scales together in a summary table showing all 9 included studies. The overall rating goes from good, high score in Newcastle Ottawa Scale (NOS)

and low risk in RoB2, to poor, low score (NOS) and high risk (RoB2) as you move from left to right. This clearly shows the study by Donnarumma and co-workers as the only one of the group to score in the 'Good' or 'Low' risk area.

CHAPTER 5: DISCUSSION

"…bruxism events increase the likelihood of dental problems." (154).

The purpose of this systematic review is to determine from the literature how effective is the most frequently evaluated form of AB management to reduce the behaviour in teenage and adult humans compared to other interventions. In searching for a frequently evaluated management technique for AB with valid research backing, that means that whilst based on numbers alone it would appear that biofeedback is the most evaluated, from the point of view of quality of research backing and immediate validity of the described mode of management, the numbers are spread evenly between the four modes of management with one study each:

- Biofeedback
- Email reminders
- Habit-reversal
- Counselling & Self-management

Much research effort has been devoted to all aspects of sleep bruxism, but nowhere near as much research has been carried out on awake bruxism (189).

For this discussion, management, treatment and any type of therapy for AB will all be referred to as much as possible as management.

There is one word which appears to be highly relevant to both sides of this human behaviour conundrum – "awareness" (195).

In many of the studies reviewed for this systematic review, both included ones and excluded, awareness is one of the most frequently mentioned words. For most patients the first hurdle to overcome in the management of the behaviour is their total lack of awareness that they indulge in the behaviour. In addition to this is the awareness that we as practitioners have to have that most of our patients are awake bruxers.

One of the excluded studies states it succinctly: *"…. patient awareness of their problem seems to be the most relevant therapeutic tool in the clinical approach of bruxism"* (196). Then later in their conclusion: "….. *patient's awareness about their problem and the application of a conservative*

therapy based on self-care was effective in reducing the wakefulness bruxism and the pain that accompanies it in these patients"

In this context, the subject of Ecological Momentary Assessment (EMA) is highly relevant as it enables an on-time report of the condition under study, which is the basic principle of all EMA approaches (197). One of the problems confronting researchers into AB is the collection of good reliable data close in time to the experience. Previously collection of data for AB was dependant on recall. This is for a behaviour that we know the majority of people are notoriously unaware of. Progress in smartphone technology has recently opened up a new era for EMA. A novel smartphone application, BruxApp, has been developed to apply EMA principles in the study of AB (173) .
A study by Colonna and co-workers suggested that a smartphone-based EMA approach may be useful to monitor AB over time and to increase an individual's awareness with respect to single-time report (166). In addition the value of EMA in the management of AB is being realised more and more (155), (198). The use of it generates and maintains patient awareness (166), (199).

Out of 9 included studies in this review examining the management of AB, 3 use biofeedback for management 2 use music as a therapeutic tool and 1 each uses drugs, email reminders, habit reversal and self-management. This means that at first it would appear from an examination of the literature, that biofeedback is the most frequently evaluated form of management for AB.
However of the 3 studies using biofeedback, the Pfeiffer and co-workers study of 2021 used an intra-aural device individually made from an impression of the ear canal for each of the 7 participants. Only 2 participants completed the course, the other 5 dropped out for various reasons within the first 2 months of the management program. It was not clearly established, either by the authors themselves or with reference to other research, that such a device is a valid way of reminding patients about their oral behaviour habit. A few months after completion of the study the device was withdrawn from the market.
The Watanabe study of 2011 included 20 subjects with 10 in a control group and has some considerable reservations. The trial ran for 4 days, with days 1 and 4 for setting up and debriefing, days 2 and 3 actual testing. In the discussion the authors state: "*that although there was a significant difference between the two groups on days 3 and 4 it is impossible to confirm from the results of this study whether such an effect lasts for longer periods"*. Later in the discussion they state: *"Of*

course, a four-day experiment including only two days of training sessions is not long enough to completely investigate the regulation of daytime clenching".

This leaves the Manns and co-workers study of 1981 representing biofeedback as a viable form of AB management.

The two studies examining the effect of Guided Music Listening (GML) on AB had similar conclusions to each other. That whilst music did make a statistical difference to the level of masseteric tension in patients, it was clinically insignificant. The conclusion from this is that GML could be a useful accompaniment in a multipronged approach to AB management but not a primary or sole form of management.

The study examining Quetiapine therapy was especially for patients who developed bruxism as a side effect to SSRI therapy for Major Depressive Disorder (MDD). So is of limited relevance for most awake bruxers. It does however raise the subject of other individuals associated with patients who develop AB (200), (201). The patients' carers, friends and relatives can find the patients' bruxism quite disturbing and from the literature they can often be the driving force behind the request for management of the behaviour. Possibly there are subgroups of bruxing patients for whom drug therapy is appropriate (202). In addition there are cases of extreme bruxism who need a temporary circuit breaker to allow the muscles to relax (203). Also there are patients who are chronic awake bruxers, not necessarily extreme, who find it an ingrained habit that is very difficult to break. For them intramuscular injection of the appropriate drug (usually Botulinum toxin) disables masseters or temporalis somewhat, sufficient to provide a forced rest to help reduce the behaviour and change a long-term habit (204). Overall, however, drug therapy would probably not be a first-line mode of management.

Looking at the 4 above studies, the patients in all achieved significant reductions in awake bruxing levels according to which measure was used in the study. Then it is a matter of the way in which those reductions were achieved.

In the Manns and colleagues biofeedback trial 33 patients went through 14 sessions, roughly 5 per week. Each session was divided into 3 stages, each lasting 15 minutes; 15 minutes Audiostimulation in both ears, 15 minutes of EMG biofeedback in both ears and 15 minutes of simultaneous Audiostimulation in one ear and EMG biofeedback in the other ear.

In the Rosenbaum & Ayllon habit-reversal trial 4 clients, each with a slightly different problem,

went through habit-reversal training which lasted about 60 minutes. For 2 of the clients 'treatment 2' was relaxation and stress management, which lasted about 75 minutes. Follow up sessions were scheduled 1 month and 6 months later for 3 of the clients. For the 4th it was done over the telephone as he had moved out of town. One good aspect of this study is that reductions in clenching activity were fairly immediate and then maintained over the 6 and 12 month follow ups.

This means that both these studies required considerable time input on the part of the participants at the start of the study.

However, both these therapeutic techniques, biofeedback and habit-reversal, have a long history. Habit-reversal in particular goes back to the 1930s (205), (206), (97). The use of biofeedback in dental therapy at least to the 1970's (207), (208), (209), (94), (95) and has made regular re-appearances since then, with EMG biofeedback being the most frequently used.

The Takeuchi-Sato and colleagues trial used a specifically designed email-based recording and reminding system which proved to be significantly better than sticky note reminders or no reminder at all. This would not be readily available to many private dental practitioners. Dental hospitals and university researchers would need to develop their own before being able to run a similar management scheme.

The last of the nine studies included in this systematic literature review is the one by Donnarumma and colleagues. This stands out from the group as the one of instant application and use in general dental practice. The first-line noninvasive approach (FL-A) consisted of: -

1. Patient education (counselling)
    - Monitor and avoid oral behaviours. Inform the patient that bad oral habits do not self-correct
    - Advise patients "Lips together teeth apart"
    - Practice the "N" exercise – say "N" quietly to yourself 3 or 4 times and then just close the lips. That is the appropriate distance apart for the teeth
    - Use sticky notes around the home and workplace as reminders to control the position of the jaws and avoid sustained tooth to tooth contact.
2. Home exercise regimen
    - Massaging masseter muscle with contra-lateral hand, thumb in the mouth 1st, 2nd and 3rd fingers on the muscle exteriorly
    - Massaging temporalis muscle with ipsi-lateral hand 1st, 2nd and 3rd fingers
    - Muscle stretches
    - Co-ordination exercises. *"They were asked to slowly open and close their mouth 20 times with their index finger placed on the lateral pole of the TMJs. They had to control the mandibular excursion while opening and maintain the mandibular dental midline parallel to a vertical line traced on a mirror"*

- Use of hot or cold packs where appropriate and advised

Whilst there was considerable evaluation of participants at the start and correspondingly occupation of their time, in a private treatment environment EMG recording, pain and anxiety questionnaires and Pressure Pain Thresholds would not be needed.

The authors stated some limitations of the study:

- There was no control group. However as the participants in the study were all patients in pain who presented requesting treatment, it would have been ethically questionable not to treat some patients
- There were only women in the study. it is possible the findings may not apply to men
- The EMG recording period was relatively short (20 mins.) and recordings were made without the use of a craniostat
- There was reliance on self-reports from participants to measure compliance with FL-A. Ecological Momentary Assessment may have increased the precision of these measurements

At the conclusion of the paper in a "Highlights" section, the authors state specifically that:

"General practitioners could implement the conservative FL-A protocol described in this study for initial management of patients with mTMD and low pain-related disability, at least in the short term."

Evaluation of quality/risk of bias for the included studies is shown in tables 3, 4 and 5.

Table 3 shows evaluation of the 5 case-control studies, with Pfeiffer (intra-aural biofeedback), Rosenbaum (habit reversal) and Zandifar (drug), scoring either 1 or 0 and Cioffi and Imbriglio at a median level. As previously discussed, the latter two studies are not considered first-line forms of management by the authors themselves.

Table 4 shows the 2 cohort studies with Manns (biofeedback) scoring slightly less than Donnarumma (counselling and self-management), neither study having a control group.

Table 5 shows the 2 randomised control trials: Takeuchi-Sato (email reminders) and Watanabe (biofeedback) with a high risk of bias for both.

Table 6 shows a summary of quality/risk of bias assessment for all 9 included studies.

The above study (Donnarumma) is the only one achieving a good score with the Manns study rating a median.

The remaining 5 studies either rated poorly on the Newcastle-Ottawa scale or at high risk of bias on the RoB 2 scale.

It is worth noting at this point that for 7 out of the 9 included studies in this review, the primary motivating issue for the authors of the study and the principle reason for running the study was pain,

the pain of TMD and it's reduction. Recent studies looking at the prevalence of TMD in various populations have figures varying between 16% and 30% (210), (211). With the incidence in women consistently being higher than men. Over the years estimates of the incidence of AB vary hugely (0.3% to 92.%) (212), partly because of its cyclical nature. But several researchers in the area have the view that we are all awake bruxers at one time or another in our lives (14). The two harmful effects of AB are oro-facial pain (the principle initiating factor in 7 of the 9 included studies) and tooth damage, the physical damage to the teeth ranging from chipped teeth, cracked teeth, broken restorations, cusps snapped off, whole crowns snapped off and finally vertical splitting of the roots necessitating extraction of the tooth (213), (163).

If one were to take the higher of the 2 figures above for the incidence of TMD, the supposition could be made that that still leaves up to 70% of the population who could be awake bruxers, damaging their dentition, causing if not physical pain, financial pain, who are largely unresearched. This would appear to be a significant gap in the research population of this subject.

The second aim of this literature review is to see how the most frequently evaluated form of management compared with other forms of management. For 8 out of the 9 studies there was no comparator and only 3 studies had a control group. The one study with both a comparator and a control group is the Takeuchi-Sato et al study. They primarily looked at the effect of an email based recording and reminding system for limiting AB in participants but, in addition to a control group, had a third group who were instructed to place in excess of 10 sticky notes at various strategic places around their place of work and at home. Whilst the sticky note group achieved a reduction in AB activity in comparison with the control group, the reduction was not as significant as that achieved by the email group. Beyond that, there is no evidence to evaluate the four forms of management, biofeedback, email reminders, habit-reversal and self-management with each other or to any other form of management.

However these varied forms of AB management together with others detailed below, possibly suggest that good AB management will require several different techniques personalised to the

individuals involved rather than a one size fits all approach.

This brings us to other forms of management for AB behaviour.

5.1 BOTULINUM TOXIN TO MANAGE AB

In the full text review category in this study there were 210 papers. Inclusion and exclusion criteria were applied to this group, hence the reduction to 9 studies in the final group.

In the large group of studies that were subjected to exclusion criteria were a significant number (35) studies related to the use of Botulinum toxin, BoNT, in the management of bruxism and related maxillofacial issues.

BoNT is produced by a bacterium Clostridium botulinum which has both medical and lethal applications. C. botulinum produces seven BoNT stereotypes (A to G). The most potent one is A followed by B and F. A and B are the only ones that have been manufactured for clinical use (145). The best known commercial name for it being Botox.

In 1973 an American ophthalmologist Alan B. Scott published the results of strabismus treatment using BoNT on monkeys and later that decade he was the first person to use it to treat blepharospasm and strabismus (214).

The application of it in oral and maxillofacial areas began in 1982 with Carruthers using it for frown lines (215) and in 1990 it was used for a bruxism patient with a brain injury (216). Later that decade Freund and colleagues used it successfully for treatment of temporomandibular disorders (217).

The use of it for TMD and bruxism has steadily grown since then.

The osteopenic consequences of injecting BoNT into masticatory muscles was examined, but it was not found to cause a consistently detectable decrease in trabecular bone density in women (218). A group of 73 patients were split into 3 groups: group A wearing a splint, group B BoNT treatment and group C both splint and BoNT. The splint had to be worn for 12 hours daily for 6

months, it was concluded that patients treated with BoNT may not need a splint. In addition the authors made the comment that splint wearing requires compliance whereas BoNT doesn't (219). Three papers agree that while BoNT treatment does reduce pain for TMD sufferers and bruxers, for around 30 days for TMD and up to 90 days for bruxers, there is not yet sufficient evidence to consider it a primary treatment. More an auxiliary to other forms of management (220), (221), (222).

A systematic literature review conducted in 2019 looked at the efficacy of botulinum toxin in the treatment of bruxism. Of the 68 studies identified, 4 RCTs fitted their inclusion criteria. These studies show that BTX-A injections can reduce the frequency of bruxism episodes, decrease pain levels and maximum occlusal force generated, in addition it offers superior efficacy in the treatment of bruxism compared to control groups treated with placebo or traditional methods for the treatment of bruxism.

Their conclusion was that "*Infiltrations with BTX-A are a safe and effective treatment for patients with bruxism, so its use is justified in daily clinical practice, especially in patients diagnosed with severe bruxism."*(223)

A second systematic literature review from 2021 looked at "*Clinical outcomes of botulinum toxin type A injections in the management of primary bruxism in adults*".

On the one hand, only 2 of the 10 selected studies in this review assessed more than 30 participants. Additionally no study compared the different brands of BT. However based on the findings of this systematic review, the following conclusions were drawn:

1. Botulinum toxin type A injections are effective in the treatment of the symptoms of primary bruxism in adults.

2. Randomized clinical trials are still needed to establish a protocol for using botulinum toxin as an alternative to traditional therapies in the management of primary bruxism (224).

There is general agreement that the effect of intra-muscular injection of BoNT lasts for around

90 days with bruxers.

Therefore it can be, justifiably, asserted that the intramuscular injection of Botulinum toxin in the management of awake bruxism is only treating the symptoms, not the cause.

However, for some chronic awake bruxers, their muscles of mastication can be in spasm and the habit of such long standing, such that this gives them an instant and forced rest. They are simply unable to clench with the same intensity or frequency. It also provides relief time to work on self-management to break away from the habit. So in this way the BoNT treatment could be a valuable addition to other forms of management particularly self-management.

Non-invasive treatment with BoNT is now the most performed aesthetic treatment in the world using a variety of types of it that have different properties. To maximise accuracy in the clinical application of BoNT, ultrasonography can be used to guide the needle in the delivery of the percutaneous intra-muscular injections (145). In the dental treatment setting however, that is only occasionally used (225).

5.2 MANAGING AB TO AFFECT SB

AB and SB are now generally considered to be two different behaviours. However there are some links which show from time to time in researching both. One of those is that managing AB to reduce the frequency and intensity of the behaviour, can have an effect on the occurrence of SB in the same individual. In a study regarding EMG biofeedback (EMG BF) to improve AB tonic events, the subjects chosen were from among those who did not experience severe pain. The EMG BF was administered during the day but EMG activity was only measured at night.

The results of this study suggest that EMG BF to improve AB tonic EMG events can also provide an effective approach to the regulation of SB tonic EMG events (3).

Another study set out to explore whether awake and sleep bruxism interact in their associations with painful temporomandibular disorders (TMD) and whether the interaction is multiplicative or

additive. This was a large study with 705 participants sourced from 3 American universities between August 2003 and September 2006. The findings of this study indicate that both awake and sleep bruxism are considerably associated with painful TMD, and that their total effect exceeds the sum of the individual effects (226). Whilst this is not directly related to the management of AB it does however show the need for its management especially in light of the figures from Winocur and colleagues 2011 (188), that awake bruxism increases the odds for sleep bruxism 5- fold (and vice versa) suggesting that the two entities have much in common.

A study by Saito-Murakami and co-workers in 2020 examined sleep bruxism regulation by daytime clenching control using a single-channel auditory EMG BF device. 20 subjects were split into Biofeedback and control groups. The anterior temporalis muscle on the habitual mastication side was selected for EMG recording. However, it should also be noted that the findings of this study are based on the recording of the EMG data for one night only. The results of this study suggest that EMG BF training for AB as a cognitive–behavioural therapy can be effective in controlling AB and in addition regulating SB in terms of both tonic and phasic muscle activities (227).

5.3 DRUGS TO MANAGE AB

In this literature review there is one study using a drug (Quetiapine) to control and eliminate AB in patients who are taking SSRIs. Various other drugs have been used, both in this context and others and are referred to in the literature. A single case report refers to the use of cannabidiol (CBD), the non-psychoactive component of the plant Cannabis sativa. A single patient who developed AB as a result of frontotemporal dementia. Evidently there is no standardized pharmacology treatment for bruxism in patients with this type of dementia. This patient's AB was almost completely relieved after this intervention (228).

Yi and co-workers reported on two patients with diurnal bruxism in whom a bilateral frontal lobe

injury resulted from haemorrhagic stroke or traumatic brain injury. They conclude by saying that further study is needed under blind and controlled conditions (142).

In a literature review of antidepressant induced bruxism from 2019, the authors conclude that "*If a patient with bruxism is responding to an antidepressant then trial of occlusal guard and medication dose reduction should be a first step. If lowering the dose of antidepressant fails, addition of buspirone should be considered next followed by other medication options*". The other medication options that their review revealed were gabapentin, mianserin, agomelatine, amisulpiride, duloxetine, escitalopram, amitriptyline, tandospirone, aripiprazole, trazodone, and Botox treatment (229).

5.4 OTHER FORMS OF AB MANAGEMENT

In 1949 one of the most frequent "treatments" of the day was occlusal adjustment. Indeed Sumner said it was needed in all cases (166). There were dissenting voices even then (84).

More recently it has been shown that there is no high quality evidence supporting the use of these irreversible techniques (137) and other authors have maintained that attitude since (230).

More recently a study shows that occlusal adjustment is a form of management that takes a long time to die. Ommerborn and colleagues in a paper in 2011 examined "Therapies most frequently used for the management of bruxism by a sample of German dentists" – 85% of experts disagree with the statement that SB is caused by occlusal interferences whereas only 47.7% of GPs disagree with it. This shows the need of more prompt transfer of knowledge from researchers to practicing dentists (231).

Massed practice, a variation of habit reversal, was another form of "treatment" that was recommended for bruxism in general. There is no reference to AB in particular. It consisted of voluntarily clenching teeth for a specified time interval several times a day. There was some discussion both about the length of time for clenching and time interval between clenches. The usefulness of the procedure varied between studies (232).

Muscle stretching is a procedure that has been suggested at different times (233) and is an

exercise recommended by Donnarumma and colleagues in their study in this review.

5.5 THE NEED FOR MORE RESEARCH

This is a comment that appears very frequently towards the end of many studies. It does appear to be particularly appropriate with reference to AB.

A systematic literature review published in 2023 entitled:

"*Effectiveness of Biofeedback in Individuals with Awake Bruxism Compared to Other Types of Treatment*"

concluded amongst other statements that:

"*The limited number of studies included in this review was due to the fact that there are not enough studies in the literature that focused on awake bruxism. The limited number of studies included and their heterogeneity made it difficult to compile their results and provide a better meta-analysis"*(159).

In a series of three papers published in 2022 devoted to bruxism, part 2 focused on early management of the behaviour. Amongst other comments in their discussion and conclusions is the following comment:

"However, there were no studies reviewing the use of appliances in the control of tooth wear" (234), (158), (235).

The central focus of the majority of AB studies is reducing pain, muscular pain or TMD pain.

5.6 SUGGESTIONS FROM THIS STUDY FOR MANAGEMENT OF AB

With reference to the four trials in Item No. 2 above. They all achieved very useful results but some studies require special input. The biofeedback trial needs input from an EMG biofeedback machine. The email trial needs a specially set up email system which sends out emails every 30 minutes between 8a.m. and 8p.m. and additionally can receive and record responses. The habit reversal trial had four clients with an individually tailored programme for each client. The

Counselling and Self-management study in contrast comprised patient education and a home exercise regime, all of which is applicable to and usable by the majority of patients.

The recommendations from this review are three:

1. Over and above and before anything – awareness, awareness, awareness. Anything we can do or say to generate awareness of the behaviour in our patients is welcome. The majority of them are awake bruxers but more significantly are not aware that they are.
2. Use the patient education and the home exercise regime suggested in the study by Donnarumma and co-workers (194), either in whole or in part.
3. Do not do anything that is irreversible and do no harm.

5.7 LIMITATIONS OF THIS STUDY

One of the factors bedevilling most systematic reviews related to the study of AB is the lack of homogeneity in the diagnosis of the behaviour. Frequently the diagnosis of probable bruxism is based on self-report and clinical examination, without there being a consistent set of criteria across all studies involved.

Secondly there was a small number of studies (9), several of them having small patient numbers.

Thirdly several studies had short follow up periods.

Fourthly in some studies the authors were not specific about whether AB or SB or both are being studied.

Finally the specificity of AB can be very difficult to determine because of its natural fluctuation with time. An individual who is not exhibiting the symptoms of AB this month may, with life's changing circumstances, have symptoms next month (163).

CHAPTER 6: CONCLUSIONS

1. On a pure numbers basis, Biofeedback is the most studied form of AB management, with GML close behind.
2. However after eliminating trials that were non-viable, non-reproducible, second line of management or of limited application we are down to one each of Biofeedback, habit reversal, email reminders, counselling and self-management.
3. Of the managements' reviewed, the counselling and self-management study was the only one that achieved a good or low risk result on its appropriate quality/risk of bias scale. In addition counselling and self-management has potentially the broadest application to the majority of practitioners.
4. With the exception of 1 study, there are no comparators examined. In each study it is the individual form of management being examined. In the trial assessing email reminders, as well as a control group there is a third group using sticky notes strategically placed at work or at home. Email reminders performed better than both sticky notes and the control group.

AUTHOR'S CONTRIBUTIONS

Study design: DG, CP, BHH
Literature search & review: DG
Title & abstract screening AL, DG
Full text review: AL, DG, BHH
Data extraction: AL, DG, BHH
Quality/Risk of bias assessment: AL, DG, BHH
Drafting manuscript: DG

Review final version of manuscript: all authors

ACKNOWLEDGEMENTS

I am very grateful to Emeritus Professor Greg Murray and Emeritus Professor Iven Klineberg for being willing to 'take me on' for the original project.

To Tess Aitken, University of Sydney library, for setting my thinking on the right track early in the project.

To Chris Howden, Sydney Informatics Hub, for thinking guidance early in the initial project.

To Margaret Ferrie for her translation from French to English of "La Bruxomanie" par les Drs Marie et Pietkiewicz fils from "Memoires Originaux". Compared to what is in the literature, the translation is considerably more interesting and particularly relevant to AB.

To Professor Chris Peck, my thanks for picking up the reins post-Covid and continuing through the transition to this project. For helping and assisting me all the way through. In particular for his continued re-assurance and encouragement. Also for enabling the engagement of my wonderful collaborators.

My profound thanks to Professor Birgitta Häggman-Henrikson for being the adjudicator over the full text review variations, for policing the production throughout and in particular dealing with the unfathomable rigors of quality, risk of bias and presentation of the results from them.

My profound thanks too to Assistant Professor Anna Lővgren for the hours spent sifting through references, both for the title and abstract search but the full text review too.

The project would have been impossible without you both.

Last, but by no means least, to Roberta my wife, helper, life guider and partner for putting up with me disappearing to 'the snake pit' on a persistent basis for an extensive number of years, a huge thank you.

APPENDICES **Page Numbers.**

1. List of Figures & Tables

2. Data sources and search strings used

Original search carried out on 30th August 2022

A. Medline, Embase, and CINAHL search string was:

1. "awake bruxism"
2. "awake clenching"
3. "awake parafunction"
4. "awake oral behavio*"
5. "awake oral habit*"
6. "diurnal bruxism"
7. "diurnal clenching"
8. "diurnal parafunction"
9. "diurnal oral behvio*"
10. "diurnal oral habit*"
11. "daytime bruxism"
12. "daytime clenching"

13. “daytime parafunction”
14. “daytime oral behavio*”
15. “daytime oral habit*”
16. Bruxism (advanced search limited to prevention, control, therapy)
17. 1 to 16 combined with OR
18. treatment
19. therap*
20. management
21. cure
22. intervention
23. surgery
24. 18 to 23 combined with OR
25. 17 and 24 combined with AND

B. Scopus, LILACS and OpenGrey search string was:

“awake bruxism” OR “awake clenching” OR “awake parafunction” OR “awake oral behavio*” OR “awake oral habit*” OR “diurnal bruxism” OR “diurnal clenching” OR “diurnal parafunction” OR “diurnal oral behvio*” OR “diurnal oral habit*” OR “daytime bruxism” OR “daytime clenching” OR “daytime parafunction” OR “daytime oral behvio*” OR “daytime oral habit*” OR bruxism AND treatment OR therap* OR management OR cure OR intervention OR surgery

C. Trip Medical search string was the same as B. above. However the searcher had to use the ‘Pro’ version in order to download the search results. This was achieved via membership of Students 4 Best Evidence (S4BE) (236)

D. Google search string started as the same as B above but had to be reduced due to the Google word limit. Looking back at the Medline search, combinations with “…parafunction”, “…. oral behavio* ” and “….oral habit*” had scored either 1 or 0. Leaving those combinations out of the search, the word count was then below the Google limit of 32.
“awake bruxism” OR “awake clenching” OR “diurnal bruxism” OR “diurnal clenching” OR “daytime bruxism” OR “daytime clenching” OR bruxism AND treatment OR therap* OR management OR cure OR intervention OR surgery. This search achieved 3260 results. Working through those results, the results number varied up to 4610. At page 10 a message appeared saying that the remaining results were duplicates of those that had been reviewed thus far, with the offer to make them re-appear if so wished. The offer was declined. Two further Google searches were carried out. Going to ‘advanced search’ in Google and adding either site:.org to the original search string brought up 4610 responses which again shrinks to a few by page 10. The same search with site:.gov at the end evokes 870 results which shrinks to 13 by page 2. If a relevant reference was found, it was copied and pasted into a Word document. At the conclusion of the Google search, all such Word documents were converted into PDF format. All documents retrieved by the searches above were uploaded to EndNote. No hand searches were conducted for this initial search.

Literature searches 30th August 2023

These searches were conducted in a similar way to the searches done on 30th August 2022. This time the dates specified were 31st August 2022 to 30th August 2023. In addition some hand searches were carried out.

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