Deep Brain Stimulation: literature review of the unseen challenges to optimal dentistry

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Abstract

Deep brain stimulation is an implantable electrical generator increasingly used nowadays for movement or neuropsychological conditions. It was reported to cause significant morbidity and mortality when used with various dental devices.

Aims: This literature review seeks to unveil hazards, analyse current guidelines and practices, and high-light the controversies practitioners face when caring for individuals with deep brain stimulation. .

Methodology: Cochrane database, Ovid MEDLINE and PubMed searches were executed using MeSH terms "deep brain stimulation" AND "dentist*". An open (basic) search for the databases was also done. Information from practice recommendations of the Parkinson's Society UK, American Parkinson's Disease Association, National Parkinson Foundation US, European Parkinson's Disease Society, Parkinson's Australia, FDA (US), and MEDSCAPE were also analysed for insights regarding deep brain stimulation and dentistry.

Results: A total of 1,778 articles were found and screened, of which 15 were reviewed in full text and 10 were deemed relevant for qualitative synthesis.

Conclusions: Previous literature suggested diathermy use and post-treatment infections are the main concerns with deep brain stimulation. A deeper understanding of the safety concerns involving other dental procedures (including electrocautery, lasers, lithotripsy, magnetic resonance imaging, radiation therapy, and ultrasound) with deep brain stimulation use is required. In addition, antibiotic prophylaxis recommendations differ internationally. There are also concerns regarding the timing of dental interventions after deep brain stimulation and various considerations during general anaesthesia. This article arranges and summarises these concerns for the perusal of all dental practitioners.

Key words: *Deep brain stimulation, implantable medical electrical device, electrical stimulation, Parkinson's disease, dentistry*

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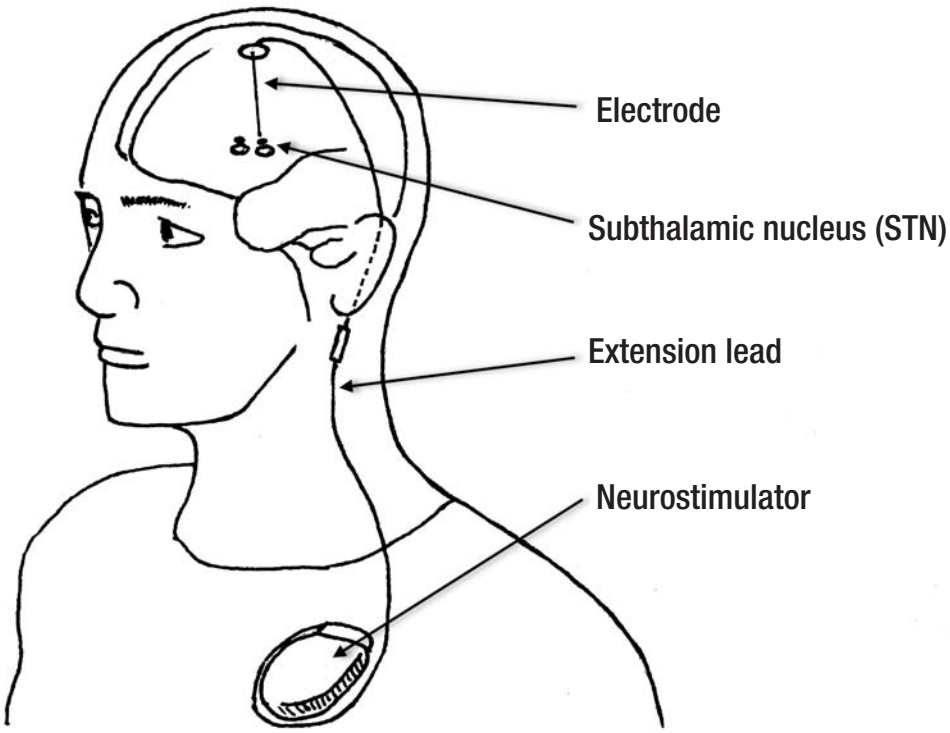
Introduction

Deep brain stimulation (DBS) is a technique by which electrodes are surgically inserted into the brain to target various nuclei within. The electrodes are connected via an insulated wire or extension lead that runs subcutaneously. They carry electrical impulses from the neurostimulator, or implanta-ble pulse generator (IPG), that usually lies subcutaneously just above the heart or at the anterior chest wall (Venkatraghavan *et al.*, 2009) (*Figure 1*).

Deep brain stimulation is indicated for various medically refractory movement disorders including Parkinson's disease (PD), Tourette's syndrome, essential tremors, dystonia, obsessive-compulsive disorders, and epilepsy (Poortvliet *et al.*, 2015). Most commonly used in individuals with PD, DBS is considered when there is reduced pharmacological

Figure 1: Components of the implanted deep brain stimulation system and targeted brain sites.



response due to tolerance, or for those who experience severe pharmacological side effects and fluctuations (on-off syndrome) (NICE, 2003). It reduces dyskinesia and motor fluctuations, decreasing the need for medications and therefore their consequent side-effects (Umemura *et al.*, 2013).

While the exact mechanism of DBS is not known, many hypotheses suggest it induces a regular axonal firing pattern in the basal ganglia through high frequency stimulation (Vanegas-Arroyave *et al.*, 2016), spontaneously inhibiting the cell bodies while generating orthodromic and antidromic axonal action potentials (Johnson and McIntyre, 2008). This mechanism also suppresses pathological β-oscillatory activities in the cortical layers (Li *et al.*, 2012), pathognomic of PD and other tremor disorders.

Only a small proportion of patients meet the clinical eligibility for DBS (NICE, 2003). It is estimat-ed that only 300 patients (PD, tremors and dystonia) per year undergo DBS in England (NHS Commissioning Board, 2013). However, a sizeable number of recent studies suggest advantages in earlier DBS intervention, with improved quality of life, motor function, mobility, and reduced levodopa-induced complications as some of the proposed benefits (Deuschl and Agid, 2013; Deuschl *et al.*, 2013; Schuepbach *et al.*, 2013). In addition, with earlier intervention, more patients will still be medically competent for the surgery. This is in contrast to the adverse effects of DBS surgery when conducted in advanced stages of disease (deSouza *et al.*, 2013). If these concepts are translated into practice, a large proportion of patients will undergo DBS and dental practitioners should expect to see an increase in patients with DBS.

Deep brain stimulation is categorised as a type of implantable medical electrical device (IMED), alongside other devices like cardiac pacemakers, electro-convulsive therapy, spinal cord stimulator, sacral nerve stimulator and gastric electrical stimulation (Maranki and Parkman, 2007; Ramos and Brull, 2015; Wo *et al.*, 2016). These neuromodulation implantable devices, although not within the scope of this article, also present users with an unequivocal dilemma due to the lack of uniform safety guidelines (Walsh *et al.*, 2015; Ghaly *et al.*, 2016).

This article aims to consolidate the current knowledge of the potential hazards of DBS in dentistry. The most severe adverse reactions involve diathermy use (Nutt *et al.*, 2001; Roark *et al.*, 2008). With such dire consequences, it is not surprising that dental practitioners fear the possibility of their electromagnetic dental devices provoking an adverse event with DBS. This limits the execution of optimal dentistry in patients. In addition, current multi-disciplinary approach to oral healthcare calls for an array of medical devices not previously used in dentistry. Examples include magnetic resonance imaging (MRI), ultrasonics, defibrillators and lasers. Many of these devices can have compatibility issues with DBS, and most dental practitioners are unaware of them. Therefore this review hopes to raise awareness of this knowledge gap.

Current literature and academic sources often discuss various implications of PD in dentistry exclusively. Few, if any, have consolidated available evidences explicit to dentistry and DBS. It is important to note that DBS is a treatment not only exclusive to PD, and although it is estimated that 125,000 people worldwide have undergone DBS since 2003, some catastrophic reactions have already been associated with dental clinics (Nutt *et al.*, 2001; Sixel-Döring *et al.*, 2006; Roark *et al.*, 2008). As a result, this

review hopes to serve as a crucial stepping stone for future research.

This article aims to:

1 Highlight safety concerns present in literature regarding dentistry and DBS.
2 Analyse current available practices and guidelines.
3 Highlight current controversies and propose further research required.
4 Summarise knowledge in a digestible and practical way for use in dental clinics today.

Methods

Selection criteria

The initial inclusion criteria were developed based on patient/problem/population, intervention, comparison and outcome (PICO). Titles and abstracts were screened in a pilot search. However, it soon became clear that these criteria and MeSH terms searches were not capturing articles appropri-ately, possibly due to the paucity of literature and variable labelling of search terms. It was evident that a more inclusive search strategy was required to bring together appropriate information dispersed across literature databases.

Inclusion criteria

As this is a qualitative literature review that does not seek to address a specific research question, the search strategy described later was used as the criteria to identify articles for review. Only articles in English were included. No timeline was set; all studies up to the present (21 May 2017) were included.

Exclusion criteria

Studies beyond safety or adverse effects of DBS in dentistry were excluded. This literature review did not cover aspects of PD, other indications for DBS, potential uses of DBS in dentistry e.g. stimulators to improve oral control or trigeminal neuropathic pain or facial pain (Gentil *et al.*, 2000; Henderson and Lad, 2006), or adverse events of DBS with devices not used within the scope of modern dentistry e.g. radiofrequency interventions (Osborne, 2009). Animal studies were also excluded.

Search strategy

The following electronic databases were used:

- Cochrane Central Register of Controlled Trials in the Cochrane Library
- PubMed
- MEDLINE (Ovid Version).

A MeSH (medical sub-heading) terms search was carried out using "deep brain stimulation" AND "dentist*" for Cochrane Library, PubMed and MEDLINE. Following this open (basic) searches in Cochrane Library and PubMed were conducted with search terms "deep brain stimulation" together with "dent*". With MEDLINE, the open (basic) search for the terms "deep brain stimulation dentistry" revealed 11,757 articles initially, of which none was categorised by MEDLINE's search engine to be 5/5 on the relevance scale. A search result with a 5/5 relevance indicates all search terms used could be found in the title, abstracts and keywords of that article; 4/5 relevance meant that one search term was omitted while 3/5 relevance meant there were two terms omitted etc.

Due to the nature of MEDLINE's open search engine being highly inclusive of non-specific non-relevant articles, it was decided that more search terms should be used, and only articles with at least a 3/5 relevance were assessed. The search terms "deep brain stimulation", "dent*" and "safety guidelines" were then used in the open (basic) search.

After relevant articles were retrieved with the above search strategy, their titles and abstracts were screened by the single reviewer. The relevant articles (according to the study's aims and objectives) were retrieved in full text. When a dilemma or uncertainty was encountered, the full articles were retrieved and revisited.

Resources on recommendations of practice

In accordance with the second aim of this study (to analyse current available practices and guidelines), the following organisations, databases, institutions were looked into based on suggestions by field specialists and experts. These sources contain recommendations specific to the practice of dentistry in individuals with DBS.

- UK Parkinson's Society
- European Parkinson's Disease Society
- American Parkinson's Disease Association
- National Parkinson's Foundation US
- Parkinson's Australia
- Food and Drug Administration US
- MEDSCAPE.

Results

Cochrane Library search

Under both MeSH term and open searches, no studies were generated.

PubMed search

MeSH term searches with "deep brain stimulation" AND "dentist*" found no articles. The open search of "deep brain stimulation dent*" revealed 143 articles which were assessed for relevance via their titles and abstracts (where available).

MEDLINE (Ovid) search

MeSH term searches [exp Deep Brain Stimulation/] AND [dentist*.mp. or exp Dentists/ or exp Dentist-Patient Relations/ or exp Dental Caries/ or exp Practice Patterns, Dentists'/ or exp Dental Care/] generated no studies. The open (basic) search with "deep brain stimulation", "dent*"

and "safety guidelines", revealed no articles of 5/5 relevance, 99 articles of 4/5 relevance, and 1529 of 3/5 relevance. The total of 1,628 articles of 3/5 and 4/5 relevance were screened via their titles and abstracts (where available). Seven articles were then assessed in full text as their content was deemed relevant.

Practice recommendations

The review of practice recommendations of DBS in dentistry from the following organisations, databases and institutions revealed various documents with valuable information (*Table 1*).

Overview of search results

A total of 1,771 studies from the searches were screened. Full text was obtained if the content was deemed relevant from the abstract. Seven documents from practice recommendations were also fully assessed, of which two were identical. After exclusion of all irrelevant articles, 10 relevant articles were used for qualitative analysis (*Figure 2*)

Discussion

DBS and adverse reactions

To understand the effects of DBS on dentistry, a brief understanding of its persistent medical concerns is required. DBS related medical side effects can be grouped into:

1 Surgical and device related: infections, confusion/delirium intracranial and cerebral haemorrhage, stroke, paresthesia, mental status change, buzzing sounds, lead fracture, dislocation of device etc.
2 Stimulation-induced: neuropsychiatric disorders (e.g. depression, psychosis, emotional liability and suicidal tendencies), dysarthria (loss of verbal fluency), postural instability gait disturbances, falls, worsening mobility etc. (Shukla and Okun, 2014)

In some studies, serious adverse events of DBS were reported in over 50% of patients (Follett *et al.*, 2010), but improved surgical techniques and handling of complications could reduce this (Fenoy and Simpson, 2014). Implant-site infection (7.7%) followed by post-surgical falls (6.0%) are the two most common serious adverse effects (Fenoy and Simpson, 2014; Bangash *et al.*, 2016).

All these side effects can adversely impact optimal oral healthcare. For example, dental treatments for patients with neuropsychiatric side effects will require special considerations in appointment-making, communication, consent-taking, oral hygiene compliance, drugs prescription etc. Each side effect should be assessed to determine special considerations required during dental treatments.

Timing of dentistry with DBS

It is prudent to avoid elective dental procedures in the first month after DBS implantation while an initial

Figure 2: PRISMA flow diagram of search string.

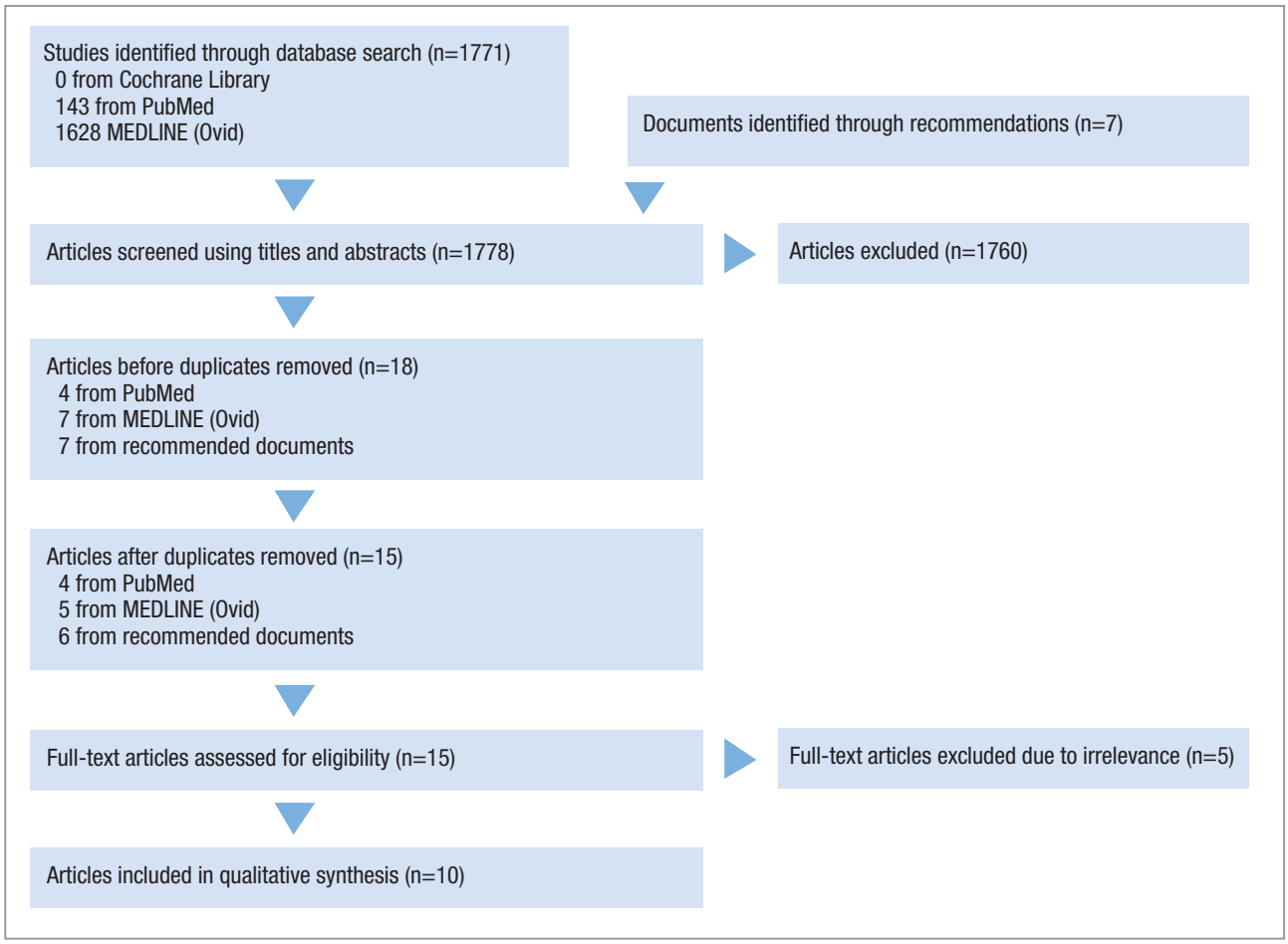


Table 1: Documents obtained from the respective organisations regarding deep brain stimulation in dentistry.

Resources with recommendations of practice regarding DBS and dentistry	Documents
UK Parkinson's Society	Arnold and Kieft, 2014
European Parkinson's Disease Society	Arnold and Kieft, 2014
American Parkinson's Disease Association	Huber, 2007
National Parkinson's Foundation US	Okun and Zeilman, 2012
Parkinson's Australia	Parkinson's Australia, 2014
Food and Drug Administration (FDA) US	Feigal, 2015
MEDSCAPE	Burgess, 2016

programming stage is being undertaken. Patients will be taken off medication while neurologists fine-tune the programming, hence motor fluctuations will be poorly controlled (Volkmann *et al.*, 2006). This can greatly affect patients' mobility, mouth opening and the ability to tolerate prolonged dental procedures. In addition, patients undergoing implantation may have their anticoagulation therapy altered (Ashkan *et al.*, 2015). Dental practitioners are advised to check with the respective physician if bleeding-risk procedures will be performed.

After the IPG programme is in place, the benefits of DBS can last at least 36 months before declining in efficacy (Weaver *et al.*, 2012). The ideal period of motor control between the first to 36 months provides a comfortable window for most dental treatments.

Tissue heating in DBS with diathermy and electrocauthery

Tissue heating by radio-frequency diathermy near conductive medical implants has been a concern for many years. Unfortunately, despite the warnings, a few incidents have occurred and not all were published (Geddes and Baker, 1989).

In 2001 Nutt and colleagues reported that pulse modulated radio-frequency diathermy was used to induce coagulation in maxillary tooth sockets for a patient with subthalamic electrodes (Nutt *et al.*, 2001). The procedure caused a vegetative state in an originally mobile and alert patient. He displayed weak corneal responses, bilateral Babinski signs, myoclonic jerks, and subsequently died. MRI revealed oedema around the brainstem that suggested substantial neurological damage (Nutt *et al.*, 2001). Another report described double vision and motor contractions when diathermy was applied over the neck area. The clinician stopped the procedure immediately and the symptoms resolved in four weeks. MRI revealed oedema around the left-sided lead (Roark *et al.*, 2008). This suggested that application of diathermy over the extension lead also resulted in damage. In the earlier report, it must be noted that the extensive irreversible damage was likely a result of prolonged exposure, with 30 minutes on each cheek, although the diathermy machine was operated at only 36% capacity at 4000Hz (Nutt *et al.*, 2001).

Consequently, manufacturers (Medtronic, Cyberonics and Advanced Neuromodulation Systems) were understandably concerned and issued warnings between 2001 and 2002 to contraindicate all radio-frequency, microwave and ultrasound diathermy exposure. U.S. Food and Drug Administration (FDA) also issued a public health notification in 2002 against the use of shortwave or microwave diathermy in implantable leads, as well as pacemakers and spinal cord stimulators (Feigal, 2015). Despite so, there is still a lack of unified consensus and guidelines for neurostimulators at present (Walsh *et al.*, 2015; Ghaly *et al.*, 2016).

Incidences of tissue heating depend on a few critical factors:

1 Distance from the diathermy applicator to the implant.
2 Length and size of the implant (smaller cross section creates high current dentistry).
3 Shape of the implant (sharp points or edges are focal points of heat dissipation).
4 Insulation covering portions of outer surface of implants (insulation reduces direct boundary between metallic implant and the tissue, leading to higher tissue heating at the metal/tissue interfaces).

It was also reported that temperature increase would be at least 5.08°C per second adjacent to the implanted DBS leads, causing severe tissue hyperthermia (Ruggera *et al.*, 2003).

The caution outlined by manufacturers still stands currently. It is stated that diathermy should not be used:

- Regardless of where the diathermy treatment is targeted
- Regardless of whether it is used to deliver heat or no heat
- Regardless of whether the neurostimulator is turned 'on' or 'off'
- In any individual components of the device system within the body.

(Medtronic, 2001)

The physics underlying different diathermies is complicated, and the manufacturers' blanket recommendations are understandably conservative. Surgical diathermy (electrocauthery) has a focused and short working distance, while shortwave, microwave and ultrasound diathermy provide dispersed energy to provide tissue heating for muscles and joints.

If electrocautery is required for dentistry in a patient with PD, the bipolar mode should ideally be used. This has been reported to be safe when used in short bursts without complications (Davies, 2005). Many experts and societies, including those in NHS neurology departments, recommend the total contraindication of unipolar diathermy (Okun and Zeilman, 2014). Others recommend only caution with unipolar types, keeping the ground plate as far as possible away from the IPG and leads such that they are not situated

between the ground plate and the surgical site (Davies, 2005). Current opinions appear to be varied and further studies are required to reach an evidence-based consensus.

Defibrillators concerns for individuals with DBS

In the unlikely case that a dental patient treated with DBS undergoes a cardiac arrest and requires emergency defibrillation, application of the Automated External Defibrillator (AED) with the same concerns as a pacemaker is advised (Venkatraghavan *et al.*, 2009). The paddles have to be positioned as far away from the IPG as possible, and perpendicularly. The lowest clinical appropriate output setting is then used if programmable, although the IPG is likely to be damaged after the enormous surge of electrical current, as in the case with a cardiac pacemaker. Evaluation of the device's function after defibrillation (Venkatraghavan *et al.*, 2009), and post-resuscitation liaison with the neurologist will be required.

General anaesthesia considerations for individuals with DBS

General anaesthesia (GA) is occasionally required for DBS patients who encounter difficulties coping with dental treatments, possibly due to co-morbid conditions or extensive dental procedures.

The main implication for DBS is electro-magnetic interference from devices used in the GA peri-operative environment. These devices include electrocautery, external cardiac defibrillation, peripheral nerve stimulation, neuraxial anesthesia, and MRI (Venkatraghavan *et al.*, 2009). In addition, interference may occur from static electricity during GA. It has been suggested that the temperature in the room should be between 20-24°C and humidity between 50-60%. Details on how static can affect the DBS components were not specified by the source (AORN, 2005).

Medical professionals should seek to obtain the various details of DBS prior to GA:

- Type and location of the DBS device
- Date of implantation and the last check
- Any anaesthetic complications during previous insertion
- Current status of the DBS device in terms of symptoms control
- Programmability of the device and how to turn it off and on (e.g. via a magnet)
- Severity of symptoms when the device is turned off
- Current medications.
  (Venkatraghavan *et al.*, 2009)

Currently, there is no available peri-operative GA guidelines for patients with existent DBS. The multi-disciplinary team (including the anaesthetist, DBS surgeon, and product representative) should hence formulate a protocol, focusing on safety, medication when the device is turned off, re-programming of the IPG, and post-surgical evaluation of the device (Venkatraghavan *et al.*, 2009).

Ultimately, consultation with anaesthetists and respective physicians is recommended. It will, however, be valuable if dental practitioners appreciate to a greater extent how DBS may adversely affect GA. This will enhance multi-disciplinary decision-making. Due to the inherent risks of GA procedures, considerations of a conservative alternative, such as conscious sedation, should also be made. Should it be deemed unfavourable, it will be judicious to defer elective dental procedures should the risks of GA exceed its benefits.

MRI concerns for individuals with DBS

Magnetic resonance imaging is widely used in dentistry from head and neck cancers, cystic and soft tissue lesions, temporomandibular joint disorders, salivary gland disorders to surgical planning. Whether MRI is safe with DBS is a source of controversies (Ruggera *et al.*, 2013). The underlying concerns include tissue level heating, magnetic field interactions, induced electrical currents and disturbance to device programmability (Rezai *et al.*, 2005). Case reports of serious injuries due to DBS devices during MRI scans have been described (Spiegel *et al.*, 2003; Henderson *et al.*, 2005). Since there is a wide variation in the techniques and brands of MRI, dentists must evaluate the individual complications with the manufacturer and the physician who indicated the device (Vekatraghavan *et al.*, 2009). If unsure about the risks, it is wise to seek an alternative imaging and err on the side of caution.

Radiotherapy and lithotripsy concerns for individuals with DBS

Deep brain stimulation can also complicate the use of other medical devices. Devices used in various specialties such as oral medicine include radiotherapy for head and neck cancers, ultrasound devices for soft tissue lesions, and lithotripsy for breaking up sialolithiasis (Okun and Zeilman, 2014). Electromagnetic types extracorporeal shockwave lithotripsy, similar to abdominal ultrasound for kidney stones, is more likely to cause damage to the IPG than piezoelectric types (Capaccio *et al.*, 2009).

Since the use of radiotherapy and lithotripsy in the head and neck region has a much closer proximity to the IPG, electrodes and extension leads, more caution is required. They are however not extensively described in literature.

Dental lasers concerns for individuals with DBS

Laser stands for Light Amplification by Stimulated Emission of Radiation. They are widely used medically, and in the past decade have also found many applications in dentistry including coagulation, depigmentation, gingival troughing, periodontal or endodontic disinfection and low level laser therapy (Glazer, 2010).

With regard to safety, energy accumulation on metal surfaces has been reported to cause excessive heating. In diode lasers, heat generation on contact with metal surfaces appears to be minimal (Glazer, 2010). With CO2 lasers however, the quickest temperature changes can range up to +41.1°C (Lambrecht *et al.*, 2012). Tissue level heating from the DBS device will be influenced by the type of dental lasers used (e.g. Diode, Er:YAG, Nd:YAG, CO2 etc.) and their respective properties (e.g. power, wave forms, duration etc.). One guideline recommended that laser use with DBS is not contraindicated, provided that "the laser is pointed away from the device", including leads and electrodes (Kausar, 2014). It is also prudent to seek advice from the product

manufacturers and physicians involved due to the paucity of clear laser safety evidence with DBS.

Antibiotic prophylaxis concerns for individuals with DBS

The incidence of DBS infection itself, regardless of dental procedures, is not uncommon at 4.7% to 15.2%. Generally, 85% of infections occur within the first year and S. Aureus infections are particularly likely to result in complete removal of the hardware (Bhatia *et al.*, 2010; Bhatia *et al.*, 2011).

A safety alarm in dentistry was raised due to a case of suppurative S. Aureus infection of the IPG. The patient was healthy without any prior infection other than a root canal treatment for a peri-apical periodontitis completed six weeks earlier. The author of the report suggested that antibiotic prophylaxis should be considered in all invasive dental procedures (Sixel-Döring *et al.*, 2006). Currently, neurologists in the UK recommend antibiotic cover for DBS prior to invasive dental procedures (e.g. dental extractions and surgeries) and procedures with bleeding (e.g. gingival manipulation). A referral letter excerpt from neurologists (in NHS foundation hospitals) to dentists demonstrates the recommended DBS antibiotic cover shown in *Table 2*. These recommendations were adapted from the 2009 European Society of Cardiology Guidelines by the Task Force on the Prevention, Diagnosis, and Treatment of Infective Endocarditis of the European Society of Cardiology (Habib *et al.*, 2009) and are similar to the updated European guidelines (Habib *et al.*, 2015). Despite so, it is questionable if the root canal therapy was the direct cause of infection in the reported case and the whole article should be understood in its entirety (Sixel-Döring *et al.*, 2006).

On the contrary, recommendations by a Harvard Medical School Teaching Hospital state "there is no need for prophylaxis prior to dentistry because of DBS" (BIDMC, 2014). An expert in Univer-sity of Florida suggested that the risk of post-dentistry DBS infection is theoretically even lower than cardiac pacemakers as the DBS components are extra-vascular. Although no evidence has been put forth, there was no dental-related hardware infection of DBS reported since 2006 under her care.

This creates a juxtaposition of prophylactic antibiotic considerations for both DBS and infective endocarditis between the US and the UK. No international guideline exists regarding the DBS antibiotic prophylaxis in dentistry. Regardless, it is generally agreed that antibiotic should still be prescribed based on the merit of dental considerations (e.g. if patients develop dental abscess, cellulitis etc.).

Until a national guideline is established, oral health professionals should include physicians in decision-making. Providing a description of the procedure involved (e.g. scaling, surgical extractions etc.) and their risk of bacteraemia will greatly help neurologists or microbiologists assess individual risk. Ultimately, an evidence-based approach with an expert panel is required to weigh the benefits and risks of antibiotic prophylaxis in DBS to arrive at a consensus.

Other neurostimulators and concerns with dental devices

A cadaveric test carried out by Roberts and colleagues using apex locators, electric pulp tester and electrocauthery resulted in "negligible damage" to neurostimulators (Roberts *et al.*, 2009). Their report, however, employed spinal cord stimulation that is located in the superficial epidural space (Roberts *et al.*, 2009), and may not be directly applicable to DBS that typically enters the deeper midbrain region.

There has been no report suggesting that apex locator or electric pulp tester can cause significant injuries to an individual with DBS. As there is no guideline, dental professionals should proceed with care and observe for adverse signs.

Limitations and biases of study

Limitations of literature

There is a general paucity of strong literature regarding DBS and dentistry despite screening through large amount of data and being highly inclusive. Many articles used were also not specific to dentistry. Only small sections of various articles were relevant to the aims and objectives.

To enhance the information available, an alternative form of evidence was sought. Various guidelines and recommendations produced by reputable institutions and organisations were looked into. Various experts were contacted, whenever possible, to shed light on the current practices in reality. They include the authors of some articles (Okun and Zeilman, 2012; Arnold and Keift, 2014), and experts from the Functional Neurosugery department of NHS. These recommendations on DBS in dentistry, however, are inclined towards experts' opinions.

Limitations of processes

This review was conducted by a single reviewer. There might be information or articles that were not available to the reviewer at the time this review was penned.

Keyword searches yielded suboptimal results, as articles were tagged differently. Various MeSH terms were used interchangeably like "Neurostimulators", "Neuromodulators", "Deep Brain Stimulators", or even broadly "Implantable

Table 2: Documents obtained from the respective organisations regarding deep brain stimulation in dentistry.

Oral	Amoxycillin	2 gm	30 to 60 minutes prior to procedure
If allergy to penicillin	Cefalexin*	2 gm	30 to 60 minutes prior to procedure
	Clindamycin	600 mg	30 to 60 minutes prior to procedure

* Cephalosporin should not be used in patients with history of anaphylaxis, angioedema, or urticaria with penicillin and ampicillin

(Excerpt of referral letter reproduced, with permission from National Hospital for Neurology and Neurosurgery, NHS Foundation Trust)

Medical Electrical Devices". Even in the cases where dentistry was involved, the MeSH term "Dentistry" was almost never used. This increased the challenge of consolidating information relevant to dental professionals.

In addition, this review provides the perspective from that of a dental professional. It can be different from that of medical professionals, neuroscientists, or product specialists. The author welcomes sharing and discussion.

Conclusion

In the UK, 1 in every 500 (or 127,000) people are affected by PD, and worldwide, 1 in every 3,000 people are affected (Dorsey *et al.*, 2007). As of now, DBS is indicated in 10-20% of these patients (Shukla and Okun, 2014).

This number is likely to increase because of reports suggesting improved outcomes by commencing DBS at least 5.5 years earlier (Deuschl and Agid, 2013). DBS has also been found to change the course of disease and decrease treatment complications. In addition, it has great capacity to improve movement control and quality of life (Erasmi *et al.*, 2014).

With the limited literature regarding the implications of DBS in oral health, more studies should be undertaken regarding safety of dental lasers, ultrasonics, and head and neck radiation. In view of the available literature regarding DBS antibiotic prophylaxis and diathermy, it may only be possible at present to provide a consensus based on expert opinions.

A summary of the points raised in this article is highlighted in *Table 3*. With this, dental professionals (especially special care dentists), medical colleagues, and various organisations (such as Parkinson's society UK), can provide more comprehensive care for this group of individuals.

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Declaration of interes

The author does not represent any product or brands and has no financial interest in the writing of this article. There is, hereby, no conflict of interest.

Abbreviations

AED	*Automated Electrical Defibrillator*
BIDMC	*Beth Israel Deaconess Medical Center*
DBS	*Deep Brain Stimulation*
ECG	*Electrocardiogram*
FDA	*Food and Drug Administration (U.S.)*
GA	*General Anaesthesia*
IMED	*Implantable Medical Electrical Device*
IPG	*Implantable Pulse Generator*
MRI	*Magnetic Resonance Imaging*
NHS	*National Health System (UK)*
PICO	*Patient/Problem/Population, Intervention, Comparison, Outcome*
PD	*Parkinson's Disease*

Table 3: Summary of evidence, postulated mechanisms, and recommendations of deep brain stimulation and dental implications.

Dental treatment with DBS use in PD	Availability of evidence	Underlying mechanisms of damage	Recommendations
General Anaesthesia	No reported adverse events	GA safety concerns Induction of electrical currents or static Consider altering drug regimens when DBS is turned off	• Lias with physician and manufacturer • Treat as if other IMED • Understand device, to switch on & off • Recommended 20-24°C, & humidity 50-60% • Ensure device operating post-operatively
External defibrillator	No reported adverse events	Electrical surge causing IPG damage and neural tissue heating	• Place paddles away from IPG, and perpendicular • Treat as if for pacemakers • Refer for assessment of DBS function after defibrillation
Diathermy: • shortwave • microwave • radiofrequency • ultrasound	Reported adverse events with mortality Manufacturers recommend total avoidance	Energy accumulation in various components of DBS, heat dissipation at electrodes causing tissue damage	• Avoid use no matter if DBS device is switched on or off^

Table 3: Summary of evidence, postulated mechanisms, and recommendations of deep brain stimulation and dental implications. *(continued...)*

Dental treatment with DBS use in PD	Availability of evidence	Underlying mechanisms of damage	Recommendations
Electrocautery: • Unipolar • Bipolar	No reported adverse events Manufacturers advise caution, suggesting only bipolar mode to be used	Unknown Likely due to tissue heating similar to diathermy	• Bipolar in "short burst" mode • Unipolar or Monopolar not recommended for use by NHS neurologists. Other sources suggest cautious use: to place ground plate away from DBS components • Some sources contraindicates^
Dental Lasers • Diode • Er:YAG • Nd:YAG • CO2	No reported adverse events Manufacturers advise caution	Unknown Possibly due to tissue heating from absorption of electromagnetic energy into metallic surfaces	• Single guideline advise pointing away from the DBS components, avoiding in maxilla • More research required
Magnetic Resonance Imaging	Multiple reported adverse events with severe disability	Tissue level heating, magnetic field interactions, induced electrical currents and disturbance to device programmability	• Seek alternatives • Lias with physician and manufacturer • Individualised assessments • Some sources contraindicates^
Ultrasound procedures	No reported adverse events May affect ultrasound quality if microphone is within six inches from the IPG but not known to cause serious incidents	Unknown	• Turn off device and settings turned to zero • Avoid directing towards the leads or IPG^
Radiation Therapy	No reported adverse events Likely to damage the IPG if radiation field is nearby or directed at it	Unknown	• Adjustments for IPG to be out of radiation zone • Place protective shield over IPG
Lithotripsy	No reported adverse events Can damage IPG components	High energy ultrasound shock waves may damage sensitive electrical components in IPG	• Not recommended unless it is the only medical option. • If unavoidable, place appropriate shield over IPG that is turned off and settings to zero • Piezoelectric types can damage DBS components more than the extracorporeal shockwave types.
Antibiotic Prophylaxis for invasive procedures	Reported adverse event	Oral bacteria transiting via bacteraemia onto DBS components	• Various sources recommend no need for prophylaxis • Oral wide spectrum antibiotics 30-60 prior to invasive procedures^ • Referral to specialist to assess severity if infection occurs

Table 3: Summary of evidence, postulated mechanisms, and recommendations of deep brain stimulation and dental implications. *(continued...)*

Dental treatment with DBS use in PD	Availability of evidence	Underlying mechanisms of damage	Recommendations
Timing of DBS placement	No reported adverse events	"Off" period in first month of DBS placement to titrate medications Motor control declines gradually after 3 years of DBS use	• Individual assessment of motor and non-motor complications • Best window for dental treatment is after 1 month and within 36 months

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