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Accuracy of Predicting Treatment Adjuncts for Patients Requiring Special Care Dentistry

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A thesis submitted in partial fulfilment of the requirements for the degree of Clinical Doctorate in Dental Surgery D.Ch.Dent in Special Care Dentistry

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Declaration

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Summary

Background: Predicting the correct treatment adjuncts in special care dentistry (SCD)**,** such as non-pharmacological behavioural support, inhalation sedation, intravenous (IV) sedation, or general anaesthesia (GA), can be complex. A number of factors could influence the decision-making process on the selection. Inaccurate prediction often leads to treatment failure, disappointment of patient and their care teams, increased waiting times, resource misallocation, negative environmental impacts, and unnecessary restrictive practices. This study aims to measure and optimise accuracy in treatment adjunct selection to facilitate better clinical decision-making.

Methods: A retrospective chart review design received ethical approval (DSREC01/2023) to be performed in the Dublin Dental University Hospital (DDUH), Ireland. All consecutive electronic records of newly assessed patients who required treatment over 24 months (2020-2021) were included. A comparison was made between the treatment adjunct chosen at assessment (predicted treatment adjunct or Pre-TA) and the actual treatment adjunct ultimately provided for successful treatment (actual treatment adjunct or Act-TA). A confusion matrix was generated to establish accuracy, precision, sensitivity, and specificity when predicting each Pre-TA. Multinomial logistic regression was used to find out significant variables that impact the accuracy of treatment adjunct prediction. A prediction model was plotted to identify which features are most relevant when predicting successful Act-TA using Posit Cloud by R Studio.

Results: The records of 106 patients met inclusion criteria. Overall, the accuracy of treatment adjunct selection was 91.5%. Nine cases were deemed inaccurate predictions. Seven of these were planned for IV sedation, resulting in a low precision rate for IV sedation compared to other options. Three major reasons for inaccurate predictions were sedation failure, service availability, and medical complexity. The presence of challenging behaviour and the urgency of treatment significantly impacted the accuracy of treatment adjunct prediction ($p<0.05$). A decision tree illustrating the probability of each Act-TA was generated. The most important factors in predicting successful adjunct selection were previous adjunct use for dental care,

capacity to consent, need for multiple restorations or any extractions, and treatment plan complexity.

Conclusion: This is the first study to assess the accuracy of adjunct selection in SCD, which has revealed a remarkably high accuracy in adjunct prediction. The instances of inaccurate predictions, primarily in cases predicting IV sedation, highlight the need for improved sedation assessment and thorough medical assessment and communication. The development of a supportive decision-making tool for future treatment adjunct selection, which considers past dental history, capacity evaluation, and a clear dental treatment plan, is a significant step forward. The proposed model warrants further validation and generalisation. The study also underscores the importance of education and training in non-pharmacological behavioural support techniques. It also highlights the benefit of teaching decision science to clinicians, specifically regarding decision making in uncertainty and uncertainty tolerance. These findings suggest a roadmap for future research and practice in the field of special care dentistry.

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Scientific Outputs

Poster presentation:

- **Kunasarapun P**, Dougall A, Daly B, Donnelly-Swift E, Mac Giolla Phadraig C. How Accurate is Treatment Adjuncts Selection in Special Care Dentistry? A Pilot Study. Poster presented at: International Association for Disability and Oral Health conference; 24-26 August 2022; Paris, France.

Oral presentations:

- **Kunasarapun P**, Dougall A, Honari B, MacGiolla Phadraig C. Behavioural Support, Sedation, or GA? A prediction model for better clinical decision-making. Paper presented at: Irish Society for Disability and Oral Health conference; 6-7 June 2024; Cork, Ireland.
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List of Abbreviations

95%CI	95% Confidence Interval
A&E	Accident & Emergency
AAE	American Association for Endodontists
Act-TA	Actual Treatment Adjunct
AI	Artificial Intelligence
ASA	American Society of Anaesthesiologists Physical Grade
AUC	Area Under the Curve
BDA	British Dental Association
BeSiDe	Behaviour Support in Dentistry (working group)
BMI	Body Mass Index
CBT	Cognitive Behavioural Therapy
CMT	Case Mix Tool
COPD	Chronic Obstructive Pulmonary Disease
COVID-19	Coronavirus disease 2019
DBS	Dental Behaviour Support
DDUH	Dublin Dental University Hospital
DPIA	Data Protection Impact Assessment
DSREC	Dental School Research Ethics Committee
EBD	Evidence-Based Dentistry
EU	European Union
FEDS	Feeding, Eating, Drinking, Swallowing
French-CMT	French Case Mix Tool
GA	General Anaesthesia
GDPR	General Data Protection Regulation
GMP	General Medical Practitioner
HIV/AIDS	Human Immunodeficiency Virus / Acquired Immune Deficiency Syndrome.

HSE	Health Service Executive (Ireland)
IACSD	Intercollegiate Advisory Committee for Sedation in Dentistry
iADH / IADH	International Association for Disability and Oral Health
ICD	International Classification of Diseases
IOSN	Indicator of Sedation Need
IOTN	Index of Orthodontic Need
IQ	Intelligence Quotient
IV	Intravenous
km	Kilometre
LA	Local anaesthetics
MDAS	Modified Dental Anxiety Scale
N/A	Not Available
N_2O	Nitrous oxide (or implies Inhalation Sedation)
NCHD	Non-Consultant Hospital Dentist/Doctor
NHS	National Health Service (UK)
OR	Odds Ratio
PEG	Percutaneous endoscopic gastrostomy
PG	Postgraduate students
PREBED	PREdictors of Behaviour in Dentistry (tool)
Pre-TA	Predicted Treatment Adjunct
ROC	Receiver Operating Characteristic
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
SCAN-score	Score based on Child's behaviour, Age, and Need (tool)
SCD	Special Care Dentistry
sCMT	Simplified Case Mix Tool
SDCEP	Scottish Dental Clinical Effectiveness Programme
SDF	Silver Diamine Fluoride
SIMD	Scottish Index of Multiple Deprivation (index)
SPSS	Statistical Package for the Social Sciences (programme)

TCD	Trinity College Dublin
UDAs	Units of Dental Activity
UK	United Kingdom
USA	United States of America
WHO	World Health Organisation

1. Introduction

This chapter introduces the rationale for this study. It begins by introducing disability and special care dentistry, followed by an overview of dental treatment needs among people with disabilities. The way in which treatment is delivered is touched on here, though this is discussed in detail later, in the literature review. This section concludes exploring the specific gap in the literature that will be addressed in this thesis to justify the rationale of the study.

People with Disabilities, Special Care Dentistry, and Oral Health

According to the *United Nations Convention on the Rights of Persons with Disabilities* (United Nations, 2006), health professionals are required to provide medical services of the same range, quality, and standard of care to people with disabilities, without discrimination. Terms are commonly used interchangeably between 'people with disabilities', 'people with impairments', 'people with special needs', 'people with special healthcare needs', and 'people with complex needs' (Glassman & Subar, 2009). Within a field of oral health, *Special Care Dentistry (SCD)* has played an essential role in supporting people with impairments in terms of dental education, prevention, and treatment. Identifying people who require SCD has no clear consensus and consequently the services remain *ad hoc*. Patients may often need an adaptation of tools, facilities, treatment modalities, and local circumstances at various levels, including service or policy levels (Bogner et al., 2024). Faulks and Hennequin defined people requiring SCD as 'those with disabilities or activity restrictions that directly or indirectly affect their oral health, within the personal and environmental contact of the individual' (Faulks & Hennequin, 2006). The concept and scope may differ between countries and regions (Faulks et al., 2012) and examples of people requiring SCD include those with, but not limited to, physical, sensory, intellectual, mental, medical, and social impairments (Britton & Bradley, 2021; Dougall & Fiske, 2008a). Lastly, Glassman et al. gave examples of patients who may require some additional supports for treatment in seven groups, which include those with (1) cognitive impairment, (2) dental fear or anxiety, (3) difficulty in sitting in a dental chair or remaining still enough to receive dental treatment, (4) extensive dental needs that would require prolonged period of time, (5) dental procedures that are difficult to be performed

under local anaesthesia, (6) complex medical problems, and (7) requirement of sedation or anaesthesia for a safer manner of the procedure and the patient's underlying conditions (Glassman et al., 2009).

It has been largely reported that people with disabilities have more oral healthcare issues than their peers without disabilities (Diz Dios & Kumar, 2022; Anders & Davis, 2010). They are living longer as life expectancy is gradually increasing all over the world, including Ireland, due to the advancement of medicine (Kontis et al., 2017). There have been several studies on oral health problems in people who require SCD, for example, patients with autism spectrum disorder, Down syndrome, dementia, and medical issues. Patients with autism spectrum disorder often exhibited higher dental caries prevalence, poorer oral hygiene, and worse periodontal health, with unmet needs for dental treatments (Jaber, 2011). Moreover, higher prevalence of dental trauma and self-inflicted oral injuries were reported for children and young adults with autism spectrum disorder (Sami et al., 2023). Patients with Down syndrome have often been described as exhibiting periodontal disease as a manifestation of their genetic disorder. This increased prevalence can be explained by anatomical and configurational abnormalities of dental tissues, cognitive and dexterity difficulties in maintaining optimal oral hygiene, and increased susceptibility to infection (Ferreira et al., 2016), as well as the abundant accumulation of subgingival periodontal pathogens (Novoa et al., 2020). Superimposed on this finding, functional limitations due to hypotonia and macroglossia exist alongside malocclusions, such as crossbite and severe crowding, which present further challenges for patients with Down syndrome. (Alkawari, 2021). People with dementia often present with increasing oral frailty and medical complexity as the disease progresses, and their oral health deteriorates especially in the advanced stage. Poor oral hygiene, dental caries, periodontal disease, and denture problems are among the top dental issues, alongside reduced levels of cooperation, which demand additional behavioural supports for treatment (Dougall & Fiske, 2008c; Marchini et al., 2019). To sum up, it is clear that there is a significant dental treatment need for people within many types of disabilities in order to address their increased susceptibility to oral disease. Furthermore, the maintenance of good oral health is indispensably essential in patients with underlying medical issues to minimise risk of systemic

impacts, infections and oral complications. For example, it has been shown than an improvement in oral hygiene in patients with dysphagia can reduce risk of aspiration pneumonia in people who are susceptible to respiratory infection (Dong et al., 2021; Khadka et al., 2021). For patients undergoing cancer therapy, it has been demonstrated that it is important to minimise the risks of oral complications by maintaining good oral hygiene, facilitating preventative programmes, and providing frequent dental follow-up visits (Levi & Lalla, 2018). The overarching importance of addressing the dental needs of this group is clearly stated in a clinical guideline for providing care for people in this group (The Royal College of Surgeons of England & The British Society for Disability and Oral Health, 2018).

Difficulty Delivering Oral Healthcare for People with Disabilities

Although dental care is important for patients who present with complex needs, it is sometimes challenging to provide safe and effective dental treatment in a regular dental setting according to their dental fears, infection concerns, cooperation issues, physical impairments, or the complexity of their medical status (Dougall & Fiske, 2008a; Coffey et al., 2023; Pine et al., 1998). Many individuals may require extra behavioural supports to achieve equitable oral health outcomes (Glassman, 2009). In the past, general anaesthesia (GA) was believed to be the only method to provide dental treatment for people with “special needs” (Grytten et al., 1989) with historically higher reported rates of dental treatment under GA and little else available (Sami et al., 2023). In recent decades, a number of additional strategies have been proposed and developed, which include continuing caries prevention strategies, social support, psychological support, physical support, behavioural support, sedation, and GA (Glassman et al., 2009). Indeed, forty-two specific techniques under the umbrella term of behavioural support in dentistry were distinguished in a recent Delphi study (Mac Giolla Phadraig et al., 2024). It seems that a range of techniques are essential to provide quality care for people with disabilities according to their needs and preferences.

Broadly, these techniques can be grouped by mode of delivery and intended outcome into four groups: Routine dental setting means a standard dental unit without sedation or GA. It may be used in conjunction with local anaesthesia for pain management, and a range of non-

pharmacological behavioural support techniques (Mac Giolla Phadraig et al., 2020a); inhalation sedation with nitrous oxide and oxygen; intravenous sedation (IV) with midazolam (Scottish Dental Clinical Effectiveness Programme, 2017), or GA, recommended for patients who require anaesthesia for safe effective care (Geddis-Regan et al., 2022).

Treatment planning in SCD is not only a comprehensive schedule of dental treatment, but also the selection of an appropriate treatment modality to facilitate safe, effective, and acceptable dental care. It has long been advocated that a concept of minimal restriction should be adopted in order to allow the patients to develop coping skills and relationships with dentistry (Lyons, 2009). In line with concepts of minimal intervention dentistry, prevention and control of oral disease and minimally invasive operative interventions were suggested (Heidari et al., 2020). The planned modality should be based on a step-wise approach by beginning with the least restrictive approach prior to the more restrictive techniques, such as sedation or GA, in order to allow the accomplishment of clinical outcomes (Intercollegiate Advisory Committee for Sedation in Dentistry, 2020; Scully et al., 2007). In recent decades, the risk of GA for dentistry is very low (El-Mowafy et al., 2019; Worthington et al., 1998). However, patients requiring SCD may have some risks that should be carefully considered by thorough examination and consultation, if necessary (Lim & Borromeo, 2017). Also, GA does not allow patients to learn how to cope with dentistry. Therefore, GA must not be over-prescribed and should be chosen when other less restrictive modalities were not feasible (Aminabadi et al., 2017; Scully et al., 2007). A study which looked at treatment modalities in pediatric patients showed that GA was over-implemented, as there were up to 47.5% of false predictions. Almost half of the children who were referred for dental treatment under GA were able to be successfully treated routinely in a non-theatre general dental setting (Aminabadi et al., 2016). Therefore, it seems that predicting the suitable treatment modality or adjunct can offer many benefits not only to the dental team but also to the patients and their caregivers or associates. It can reduce delays in waiting for required treatment on a long waiting list, prevent an exacerbation of unnecessary fear and anxiety by being put on the wrong adjunct, increase trust, and develop better relationships between the patients and dental professionals (Geddis-Regan et al., 2024b). Financially, it can minimise the cost of treatment, transportation, and

multiple appointments. It means that hospital facilities can be utilised wisely and sufficiently with the correct adjunct selection. Lastly, correct prediction can help the dental team be less stressed by being better prepared, and not struggling to provide necessary care with a sub-optimal adjunct and reduce duplicated works when treatment fails and needs to be rebooked.

Decision-Making and Adjunct Selection

Several factors can influence the decision to choose the most appropriate treatment adjunct. Making a decision on which treatment modality is the most appropriate for each individual is complex (Boyle & Lane, 2020). The first three main justifications historically are usually the patient's systemic condition, level of cooperation, and nature of the treatment procedures (Prabhu et al., 2008). However, Messieha (2009) suggested that financial issues, human resources, availability of facilities, and legislation must all be considered altogether to gain a more holistic picture (Messieha, 2009). Glassman (2009) suggested there should be additional factors evaluated prior to the selection of treatment adjunct, including the patient's past and current medical status, complexity of the planned procedure, time and effort to provide and receive treatment using a multi-staged approach, cost, side effects of any aspect of the treatment, social and environmental factors, availability of treatment modalities, and urgency of care (Glassman et al., 2009). However, there is no such study to confirm a significant association between any of these factors and the outcome of treatment adjunct selection, nor is there guidance that leads to the best decision for each patient. Even most published guidelines for the use of sedation or GA for dental treatment do not include such considerations in SCD (Glassman, 2009).

In order to support a better decision-making process in the selection of treatment adjuncts, a suitable tool or model would provide a promising resource to assist clinicians in this regard. A study by Fuhrer et al. (2009) implied that there was no such tool to support the selection between behavioural support techniques, sedation, or GA (Fuhrer et al., 2009). Presently, there is still no exact tool to enable the provider to choose the most appropriate treatment modality in SCD. Thus, a supporting tool for decision-making of treatment adjunct selection in SCD is strongly required. Some existing tools and models explored a broad decision between

non-pharmacological and pharmacological modalities, while the others focused only on the need for GA or in a paediatric group. These include the Indicator of Sedation Needs (Coulthard, 2013), the PREdictors of BEhavior in Dentistry (PREBED) model (Varela et al., 2021), the SCAN-score (Score based on Child's behaviour, Age and Need) (Berat et al., 2024), a framework for proportionate adjunct selection based on the degree of patients' dental anxiety (Newton et al., 2012), and the Seattle Care Pathway (Pretty et al., 2014). In the modern era, any discussion on decision-making in healthcare must also consider the invention of artificial intelligence (AI) and machine learning, which have a growing impact on healthcare and dentistry (Carrillo-Perez et al., 2022). Its application has the potential to support both treatment planning and treatment procedures.

Study Rationale

At the Dublin Dental University Hospital (DDUH), Trinity College Dublin (TCD), a Special Care Dentistry clinic has run for almost 25 years to provide secondary or tertiary care to patients with disabilities. A monthly assessment clinic is set up to assess newly accepted patients referred from primary care throughout the country. Then, these patients are allocated to one of the waiting lists according to the planned treatment modalities. Four main treatment modalities available in the DDUH include:

- Routine clinic (non-pharmacological behavioural support) (Mac Giolla Phadraig et al., 2020a; Lyons, 2009)
- Inhalation sedation with nitrous oxide (N_2O) and oxygen
- Intravenous sedation with midazolam (IV)
- General anaesthesia (GA)

Using data from this service, this study aimed to investigate the accuracy of the prediction of treatment adjuncts at the assessment visit, compared with the actual treatment adjuncts used to provide dental care over the course of treatment. Moreover, it was expected that the factors that influence the accuracy or inaccuracy of the prediction would be identified. We envisage that understanding the accuracy of the past adjunct selection, as well as its influencing factors, will improve future decision-making processes in SCD. Lastly, using the data extracted from

the study, a proposed prediction model could be constructed to assist in better prediction of treatment modalities. Following this study, it is hoped that AI and machine learning can be integrated in order to develop a supporting tool for future decision-making in the treatment adjunct selection in SCD.

Conclusion

In order to provide safe and effective dental care for people requiring SCD, additional inputs may be required to allow high-quality clinical achievements. These can be the use of non-pharmacological behavioural support techniques, pharmacological sedation, or GA. Due to many differences in providing each treatment modality, such as equipment, location, human resources, and preparations, it is beneficial to select the most appropriate treatment modality for each patient correctly. Inaccurate prediction can lead to a number of drawbacks for both patients and dental teams. The following section will include the current reviews of the literature on behavioural support techniques in dentistry, decision-making in dentistry, and the existing tools or models used to support decision-making in SCD.

2. Literature Review

This literature review spans a number of topics that need to be systematically considered prior to exploration of the research question. Three topics are reviewed in this narrative review by way of exposition:

1. Behaviour support techniques in SCD
2. Decision-making in dentistry
3. Previous supporting tools, models, or studies in the use of treatment adjuncts in SCD

2.1 Behaviour Support Techniques in SCD

In SCD, people with disability often come with unique challenges for dental professionals in planning and carrying out the treatment which require the professionals to have additional training, patience, empathy, and desire to be successful (Glassman & Subar, 2009). Studies in behavioural support techniques are limited outside the field of paediatric dentistry (Geddis-Regan et al., 2024b). In 2009, the Special Care Dentistry Association announced a consensus statement proposing seven suggestive methods to help people with special needs receive dental care (Glassman et al., 2009). These were:

1. GA – delivered in hospitals, surgical centres, and dental offices
2. Sedation – ranging from minimal to deep sedation
3. Behaviour support
4. Physical support
5. Psychological support
6. Social support
7. Preventive strategies

Recently, *Dental Behaviour Support (DBS)* is a newly agreed umbrella term for describing techniques or strategies used to assist patients in receiving appropriate dental treatment (Mac Giolla Phadraig et al., 2022c). This contemporary term is similar to previously used terms, such as ‘behaviour management’ or ‘behaviour guidance’ as used in the field of pediatric dentistry (Dhar et al., 2023). According to a recent Delphi study, it consists of a spectrum of distinct

techniques (Mac Giolla Phadraig et al., 2024), effectively used, alone or in combination, to support patients receiving dental care. Table 1 displays the list of 42 DBS techniques, according to the recent study by the Behaviour Support in Dentistry (BeSiDe) group. Additionally, this literature review found a small number of techniques that were not included in the list, such as aromatherapy, acupuncture, and biofeedback, which could also be efficient in managing dental anxiety (Hoffmann et al., 2022). The goals of implementing DBS techniques are to create a way of communication, limit patient anxiety, and build a good trusting attitude toward dentistry in order to deliver the highest quality of dental care (Lyons, 2009; Roberts et al., 2010). Additionally, if sedation or GA is required, it should aid the patients in fear and perception of pain depletion, more favourable levels of cooperation, and prevention of unnecessary exacerbations of dental fear and anxiety. Regarding the dental team, it also lessens stress and unpleasant emotions, as well as facilitates the accomplishment of dental procedures (Ashley et al., 2021).

Table 1: An agreed list of DBS techniques

List of agreed terminology of DBS techniques (Mac Giolla Phadraig et al., 2024)		
1. Enhancing control	15. Behaviour shaping	29. Animal-assisted therapy
2. Stop signal	16. Positive reinforcement	30. Caregiver presence
3. Counting time	17. Negative reinforcement	31. Preparatory visit
4. Timed breaks	18. Distraction	32. Desensitisation
5. Memory restructuring	19. Guided imagery	33. Graded exposure
6. Augmentative, alternative communication	20. Clinical hypnosis	34. Cognitive behavioural therapy
7. Visual supports	21. Music use	35. Systematic desensitisation
8. Message to dentist	22. Progressive muscle relaxation	36. Tell-show-do
9. Clinical empathy	23. Breathing retraining	37. Modelling
10. Non-verbal prompts	24. Social environment	38. Premedication
11. Voice control	25. Social stories	39. Sedation
12. Person-centred communication	26. Pre-visit preparation	40. General anaesthesia
13. Instruction	27. Patient-centred scheduling	41. Clinical holding
14. Reassurance	28. Sensory-based techniques	42. Protective stabilisation

Four commonly used modalities in Western Europe are communication-mediated techniques, inhalation sedation, single-drug intravenous (IV) sedation, and general anaesthesia (GA). In this study, we use the term ‘routine’ or ‘non-pharmacological behavioural support technique’, instead of the communication-mediated techniques, to represent the modality which does not involve the use of sedating medications or GA. Each technique requires different training levels of providers, staffing levels, equipment and facilities, governance, and environmental impacts (Mac Giolla Phadraig et al., 2022a). Brief descriptions of each technique are elaborated below.

2.1.1 Non-pharmacological Behavioural Support / Routine / Local Setting

Non-pharmacological behavioural support covers a wide range of techniques used in dentistry. Its main characteristic is a technique or a mixture of techniques used to provide care without the use of any medication or pharmacological sedation. It is less clearly defined and varies from simple communicative method to physical intervention (Mac Giolla Phadraig et al., 2020a). According to Table 1, almost all listed techniques are included in this group, except premedication, sedation, and GA (numbers 38-40), which involve the use of drugs to sedate or anaesthetise the patient. Physical restraint techniques are culturally sensitive. Therefore, their uses were controversial and not universally accepted. Practices, such as clinical holding and protective stabilisation, by the well-trained providers can efficiently support patient cooperation intraoperatively and minimise the need for sedation and general anaesthesia (Roberts et al., 2010; Dhar et al., 2023). Apart from these controversial techniques, the other methods have minimal restriction to the patient's right and freedom of action, compared to the pharmacologically administered interventions. They also allow the patient to develop coping skills for dental treatment and a favourable attitude toward dental care (Mac Giolla Phadraig et al., 2020a; Lyons, 2009). These benefits strengthen the fact that these non-invasive techniques should be considered prior to the use of pharmacological management (Roberts et al., 2010). However, these techniques possess certain limitations. Dental practitioners often report a lack of experience and insufficient education and clinical exposure in their undergraduate curricula (Mac Giolla Phadraig et al., 2020b), which made them less likely to accept treating patients with disability. Thus, it is important for education and training in SCD to develop the appropriate skills and knowledge in performing non-pharmacological behavioural support techniques (Faulks et al., 2012; Smith et al., 2006). By employing these techniques, many dentists are able to safely provide care to their patients in a routine fashion, without the use of sedation or GA (Lyons, 2009). Generally, these techniques are rarely used in isolation. They must be used simultaneously when providing pharmacological management (Roberts et al., 2010).

2.1.2 Inhalation Sedation with Nitrous Oxide and Oxygen

Inhalation sedation with nitrous oxide and oxygen is considered one of the basic or standard conscious sedation techniques for people of all ages (Scottish Dental Clinical Effectiveness Programme, 2017; Craig et al., 2007). It involves the titrated administration of two gases through a nasal mask and its scavenging system. Nitrous oxide provides anxiolytic and sedative effects, with a varying degree of analgesia and muscular relaxation (Ashley et al., 2021). It has been proven to be safe in managing patients with mild to moderate anxiety with minimal side effects (Yee et al., 2019). When administered, nitrous oxide rapidly enters the blood circulation through the respiratory system. Then, it can be quickly absorbed into the body tissues, including the central nervous system, resulting in a rapid onset of sedative action. When treatment is finished, recovery is swift, with flushing of 100% oxygen allowing a discharge process to begin soon after the completion of the procedure (Yee et al., 2019).

One of the requirements when selecting inhalation sedation is the competency of staff, including knowledge and skills in conscious sedation and monitoring, training in the standard of equipment use and maintenance, and basic cardiac life support skills or equivalent (Yee et al., 2019). The selection of this technique also depends on the patient's ability to understand and follow the instructions, accept the nasal mask over the nose for a period of time, and breathe with their mouth closed (Boyle & Lane, 2020). Indications and contraindications are described in Table 2. Excellent success rates of 93% of patients were reported with careful case selection (Foley, 2005). Treatment does not need to be provided in a hospital setting. The presence of a responsible escort may not be a significant factor when considering inhalation sedation as it is not usually required (Scottish Dental Clinical Effectiveness Programme, 2017). However, the presence of escorts may be beneficial when performing this technique during the first few visits, given the nature of patients in SCD. Lastly, all essential equipment and in-built safety features of nitrous oxide delivering systems need to be inspected regularly and prior to use, including gases-containing tanks, tubes, reservoir bags, and nasal hoods (Yee et al., 2019; Donaldson et al., 2012).

Table 2: Indications and contraindications for inhalation sedation

Indications	Contraindications
1. American Society of Anaesthesiologists Physical Grade (ASA) I and II 2. Patients who are mature enough to cooperate and understand Management of dental anxiety 3. Management of needle phobia 4. Management of gag reflex 5. Management of medically compromised patients who are at risk of respiratory depression from other techniques and where dental stress could trigger exacerbations, such as epilepsy and asthma. 6. Alternative adjunct to GA or when other sedative methods are contraindicated	1. Children who are too young to cooperate or understand 2. Patients who have respiratory diseases or symptoms which can lead to inability to breathe nasally, such as chronic obstructive pulmonary disease (COPD), severe common cold, tonsilitis, nasal obstruction, nasal polyp, recent severe sinusitis within 14 days, allergic rhinitis, and recent ear-nose-throat operations within 14 days 3. Patients with nasal or facial deformity 4. Patients who are in the first trimester of pregnancy 5. Patients in bleomycin chemotherapy 6. Patients with severe psychological disorders or drug-related dependencies 7. Other diseases which can cause complications from sedation, such as myasthenia gravis, multiple sclerosis, pneumothorax, otitis media (middle ear infection), cobalamine or vitamin B12 deficiency 8. Claustrophobic patients who are unable to have a nasal hood retained for a period of time

(Girdler et al., 2017; Yee et al., 2019; Ashley et al., 2021; Becker & Rosenberg, 2008)

2.1.3 Intravenous Sedation with Midazolam

Midazolam is a benzodiazepine which is usually the first choice of IV sedation technique in Western Europe (Intercollegiate Advisory Committee for Sedation in Dentistry, 2020). It has ideal characteristics for being a sedative, including its rapid onset, short half-life, and lack of active metabolites. It also has anxiolytic, retrograde amnesiac, anti-convulsive, and muscle relaxation effects. Intravenous sedation (IV) with midazolam is considered one of the standard sedation techniques for a young person or adult (Scottish Dental Clinical Effectiveness Programme, 2017). The technique involves a cannulation through a superficial vein, mostly in the dorsum of hand or antecubital fossa, in order to administer a titrated drug to the patient's response. Titration of the drug allows for a wide margin of safety (Scottish Dental Clinical Effectiveness Programme, 2017), with the clinical end-point suggested to be when the patient is sufficiently relaxed to receive the procedure while still able to maintain verbal communication with associated slowing and slurring of speech, ptosis, and partial loss of motor coordination. Its main risk is respiratory depression, which may lead to arterial hypoxaemia, because of over-sedation or medication overdose. It is usually caused by a bolus injection or an incorrect titration (Wilson et al., 2011). However, in the hands of a well-trained team following careful governance and processes, the technique offers a broader range of care, including multi-staged appointments in a non-hospital setting (Scottish Dental Clinical Effectiveness Programme, 2017).

The technique is a safe, often successful, and suitable management modality for the dentally anxious patients with and without disabilities (Wilson et al., 2011). However, it may not be ideal for those with poor venous access, needle phobia, and some underlying medical situations, especially respiratory and cardiovascular diseases. A robust assessment before the sedation visit is required (Mac Giolla Phadraig et al., 2022a). Well-trained dental staff are required to provide IV sedation as the knowledge and skills in various areas, including sedation assessment, venipuncture and cannulation, titration, monitoring, drug interactions, management of complications, and advanced cardiac life support (Coulthard, 2006). Medical emergency equipment, such as oxygen supplementation system and ventilation mask, should be ready, as well as flumazenil to be administered as an antidote (Ashley et al., 2021). For

teams who have both the training and facilities, IV sedation is usually selected as an adjunct for those patients where routine and inhalation sedation may not be suitable due to limited cooperation. At the same time, GA may be too invasive or not suitable for multi-stage dental processes. In this thesis, IV sedation is purely led by a team of dental specialists who have been well-trained in conscious sedation, using midazolam as a single sedative agent only and taking place in a dental hospital. Oral sedation with midazolam is used in certain cases to allow safe cannulation. Considerations of anaesthetist-led IV sedation, which normally takes place in a hospital setting, were not counted in this study, including the use of different agents, such as sevoflurane and propofol, and different techniques, such as total intravenous anaesthesia. Such techniques, if available, could have a significant impact on the selection of treatment modalities as they could fit well in the middle between dentist-led IV sedation and GA. Their availabilities could potentially improve the accuracy of IV sedation selection, with massive support from the anaesthetic team.

2.1.4 General Anaesthesia

Despite the availability of less invasive techniques, there has been an increasing trend in the return of the use of GA for dental treatment. GA was reported to be necessary for approximately 20% of people with disabilities to receive dental treatment (Leyman et al., 1999). Moreover, the proportion can be up to 60% in some tertiary care centres (Sigal et al., 1988). Interestingly, it was concluded that, in spite of low dental treatment needs, almost 80% of children with autism spectrum disorder required GA for their dental treatments (Alghafis et al., 2023), implying the over-prescription of GA. Some believed that poor cooperation may be the primary reason for the requirement of GA. However, the author suggested that a lack of skills to perform effective dental behavioural support techniques by the dentists was one of the main reasons of this trend continuing. (Hicks et al., 2012).

In the past, following a few complications reported before 2000, it has been proposed that GA should be performed in the hospital setting only. It should be limited to the following groups of patients (Flynn & Strunin, 2005):

1. Patients who are unable to cooperate because of immaturity or physical or mental disability.
2. Patients in whom local anaesthesia has repeatedly proved unsuccessful or is unlikely to be effective because of the extent of surgery or the presence of infection.
3. Patients with a history suggestive of hypersensitivity or allergy to the contents of the local anaesthetic ampoule.
4. Patients who suffer from extreme nervousness and who refuse to undergo any form of dental treatment while conscious.

GA can guarantee safe and effective pain control in the best environment for high quality clinical treatment (Mallineni & Yiu, 2016). It was believed that operating conditions under GA could be ideal once the patient was anaesthetised, especially those with difficulties in cooperation (Scully et al., 2007). However, authors dealing with adult populations have disagreed, claiming that treatment may not be possible due to reduced access due to uncontrolled tongue and anaesthetic airway, as well as a limitation in obtaining good occlusal determination in restorative procedures (Boyle & Lane, 2020). GA is normally limited to be performed in a hospital setting only, given the situation in Ireland and the UK. Patients with special needs can benefit from the treatment under GA as it is reported to be safely provided in a hospital-based setting, with extremely low morbidity and mortality (Ananthanarayan et al., 1998; Mallineni & Yiu, 2016; Lim & Borromeo, 2017; El-Mowafy et al., 2019). However, it still possesses greater risk of morbidity and mortality compared to other techniques (Nelson & Xu, 2015). Therefore, especially in patients requiring SCD, a thorough pre-operative assessment is essential to reduce the risk of complications associated with GA (Lim & Borromeo, 2017).

Considerations to select GA for dental treatment comprise several factors. Patients' underlying medical diseases and associated comorbidities can eminently impact the decision, similar to their lists of current medications. Physical disability and risk of airway complications could be other influencing factors (Messieha, 2009), as well as risk for peri-operative cardiac complications (Zambouri, 2007). In elderly patients, postoperative cognitive dysfunction is one of the adverse events after the GA that affects the decision (Belrose & Noppens, 2019; Vacas et al., 2021). On the other hand, healthcare factors that should be considered include the availability of an operating room facility, length of the procedure, and teamwork (coordination and communication) with the anaesthetic team. It was reported that dental treatment under GA tends to be more surgical procedures rather than restorative procedures in order to avoid the need of repeated GA (McGeown et al., 2022). Because of intraoperative unconsciousness, treating patients under GA may limit dental procedures which require patient cooperation, such as occlusal validation after restorative procedures, especially in the case of oral intubation (Boyle & Lane, 2020). On the other hand, nasal intubation, which is a more common approach for dental treatment under GA, may partly resolve the issue as it allows convenient access to the mouth (Mallineni & Yiu, 2016). Moreover, the frequency of hospital visits may be another factor. Typically, only one episode of GA is required, and in most cases, it can be completed within a day without hospital admission (Bailey et al., 2019). Only a few cases with complex medical problems may require hospital admission (Boyle & Lane, 2020). Ultimately, it appeared that the final decision to indicate GA was made as a personal preference of the practitioner rather than other considerations (Berat et al., 2024).

To date, there is no globally accepted protocol for the indications of dental treatment under GA (Mallineni & Yiu, 2016). In the USA, GA was considered medically necessary and covered by an insurance in the following circumstances: local anaesthesia (LA) was ineffective, allergic to LA, removal of two or more impacted teeth, extraction of five or more teeth, more than one surgical extraction, and other minor intraoral surgeries (Glassman, 2009).

In SCD, only a detailed clinical guideline from the British Society for Special Care Dentistry (formerly known as the British Society for Disability and Oral Health) is available to directly support the provision of GA. The guideline emphasised seven important overarching principles of using GA for dental treatment for patients requiring SCD, which are (Geddis-Regan et al., 2022):

1. It should be based on a comprehensive assessment and a clear rationale.
2. It should not be the first-choice approach unless other options are not feasible or contraindicated.
3. A significant benefit must outweigh the risk of GA itself.
4. It should be used when known or suspected conditions are identified, meaning it should not be used for routine examinations.
5. Treatment planning must take each patient's values and preferences into account, as well as medical, dental, psychological, and social manners.
6. Inter-professional collaboration should be encouraged to facilitate a holistic care approach.
7. A consultant or specialist in SCD should lead the overall process.

2.1.5 Selection of Behavioural Support Techniques

It has always been a challenging decision to make the right behavioural support techniques for patients who require SCD (Boyle & Lane, 2020; Fuhrer et al., 2009). Basically, the least invasive technique should be considered first, but the plan must balance the patient's risk and benefits with the likelihood of achieving clinical outcomes. According to the IACSD, it was pointed out that "No one technique is suitable for all patients. However, adopting the principle of minimum intervention, the simplest and safest technique that is likely to be effective, based on a robust patient assessment and clinical need should be used" (Intercollegiate Advisory Committee for Sedation in Dentistry, 2020). It is important to begin with the least restrictive modality (Scully et al., 2007), if possible, because the patients who were treated under pharmacological sedation would request it again (Goodwin et al., 2012).

Several factors have been reported to have an impact on selecting the appropriate treatment adjunct in SCD. Firstly, six domains of factors were described by Mac Giolla Phadraig et al. in 2022 (Mac Giolla Phadraig et al., 2022a). These include:

1. Ethical issue

It included fundamental ethical principles in healthcare, such as duty of care, right to health, right to access of healthcare, right to autonomy, and right to minimal restriction.

2. Patient factors

Patient factors must not be excluded from the consideration. Their physical health and psychological health, including their level of dental anxiety, must be taken into account, as well as their social circumstance, financial situation, age, behaviour, communication preference, and general preference.

3. Dentist factors

Factors from the providers' perspective included knowledge and skills in providing each behavioural support technique. The level of their training, preference, and cognitive bias can also influence the selection. It is correlated to the article which advocated the necessity of education in SCD in order for developing appropriate skills and knowledge to provide care for people in this cohort (Faulks et al., 2012).

4. Procedure

The procedure can influence the consideration of adjunct selection, such as its urgency, extent, complexity, suitability, cost, and logistics.

5. Service

Factors from the service may impact the consideration, such as the availability of services, care pathways and supports of each centre, and acceptability and appropriateness of the service according to the service of the centre. For example, a primary care hospital may not be able to perform sedation or GA, while a tertiary care hospital can do.

6. Environmental sustainability

This topic includes both environmental resources and waste. The resources included travel fuel by both patients and staff, procurement, human resources and administration, and essential public utilities, such as water, gas, and electricity. The wastes produced from each modality, such as material wastes and emissions to the external ecosystem, could be contemplated.

Secondly, Boyle and Lane described that *"it is rarely one factor which solely influences the treatment modality chosen"* (Boyle & Lane, 2020). They outlined some of the factors in their article, including patient's cooperation, complexity of dentistry, location and logistics, preferences of all relevant bodies (patient family and caregiver), previous history, medical considerations (such as allergy, psychological illness, poor veins, obesity, movement disorders), pain history, and patient's capacity to decide on their treatment. The complexity of the dental procedure could play a vital role in treatment adjunct selection as it could impact the implementation of the treatment. According to the IACSD (2020), the majority of patients could be suitably treated by an appropriately trained and experienced operator-sedationist. Both conscious sedation techniques in this study were acceptable to have a single operator-sedationist. A dedicated sedationist and a separate operator, however, may be needed in some specific situations, such as those cases having more complex underlying diseases, physical disabilities, emotional difficulties, history of being challenging to manage, prolonged procedures, or advanced ages (Intercollegiate Advisory Committee for Sedation in Dentistry, 2020).

Level of cooperation seemed to be a key factor when choosing between non-pharmacological and pharmacological techniques (Boyle & Lane, 2020). Some behaviours in daily activities could be good predictors, as well as behaviours when having a medical test or a radiographic examination (Varela et al., 2021). The level of dental anxiety and the presence of urgent treatment needs could indicate different approaches to the management of dental anxiety (Newton et al., 2012). In children, the extent and severity of carious lesions were among several considerations (Blumer et al., 2019). Moreover, additional factors involved in the decision-making process should be considered, including the patient's financial situation and availability of healthcare resources, such as an operating room and the anaesthetic team, in case of GA (Varela et al., 2021).

A study in Scotland explored the anaesthetic choices for a third molar surgery. The nature of healthcare centres and the difference in socioeconomic deprivation had significantly impacted the selection of treatment modalities. The hospital with an on-site GA theatre tended to have more GA cases, compared to the other facility where a distant site for GA was required. Using the Scottish Index of Multiple Deprivation (SIMD), patients from more significant social deprivation areas were more likely to have the treatments done under GA. There was also a substantial difference in the role of the assessor who made the decision between consultants and trainees, as well as between staff and trainees. Lastly, case difficulty presented a small significant difference, but it was concluded that this was unlikely to represent clinical difficulties when choosing a treatment modality for the surgery (Sammut et al., 2013).

In summary, each treatment modality has its benefits and drawbacks, as well as suitability. No one technique will fit all patients, but it should be considered on an individual basis. A conservative approach should pragmatically be followed by beginning with the least invasive technique, which is likely to be successful, and considering GA when the other techniques are unsuccessful (Aminabadi et al., 2016). A fundamental principle is to select the treatment modality/adjunct that is person-centred, safe, effective, and acceptable to the patient (Mac Giolla Phadraig et al., 2022a).

2.2 Decision-Making in Dentistry

Decision-making is a fundamental cognitive process that involves selecting a choice from multiple alternatives. It has been extensively studied across various disciplines, from psychology to economics. The science of decision-making examines how decisions are made, the factors influencing them, and the potential biases that can affect the outcome. Classically, three major brain mechanisms have been proposed to answer how decisions are made, which are logics, statistics, and heuristics (Gigerenzer & Gaissmaier, 2011). Firstly, a rational method uses logic, rationality, and probabilities to determine the most appropriate decision. The rational decision-making can be defined as the process that integrates all relevant information available and leads to outcomes with the most utility. The Bayesian model and the rational choice theory were among examples of the rational decision-making (Curley et al., 2019).

Although the rational approach is thought to be a normative pathway of decision-making, a heuristic model has revolutionised the field of decision-making science. The heuristic or cognitive shortcuts model is a basic technique that allows decision-makers to make decisions without using heavy cognitive computation (Tversky & Kahneman, 1974). The authors proposed three classic heuristics features: representativeness, availability, and anchoring and adjustment. During the last decade, a dual process theory of decision-making has been proposed in modern decision science, catalogued in a popular science book called *'Thinking, Fast and Slow'* (Kahneman, 2011). It was suggested that two separate parts of the mind govern how decisions are made: *system 1* (heuristic and intuitive) and *system 2* (systematic and analytical). System 1 involves heuristic and cognitive shortcuts, allowing decision-makers to make intuitive responses (Evans & Stanovich, 2013), while system 2 uses more rational, conscious, deliberative, and effortful parts to make decision. The dual process theory has been scientifically proved by investigating brain functions. Each system functioned by different parts of the brain: amygdala for system 1 and pre-frontal cortex for system 2, which could be physiological evidence of the existence of both systems (De Martino et al., 2006). The full comparison of both systems is presented in Table 3 (Croskerry, 2009).

Table 3: Principal characteristics of system 1 and system 2 decision-making

Style	System 1	System 2
Computational principle	Associative	Rule-based
Responsiveness	Passive	Active
Cognitive load	Low	High
Automaticity	High	Low
Rate	Fast	Slow
Reliability	Relatively low	Relatively high
Errors	Relatively common	Relatively rare
Emotional attachment	High	Low
Scientific rigour	Low	High

Lastly, *a unified threshold model* was proposed in order to explain both rational and intuitive processes. It was claimed that the unified threshold model is a better metaphor to use when describing decision-making behaviour. In this model, decisions are made when a specific threshold is met, and the threshold can shift to suit different situations or environments. Decision makers can adjust their tolerance for the required amount of information/evidence needed to make a decision. In other words, the intuitive decision-making is used when the threshold is low and can be easily reached using a satisfactory amount of information. Whereas the rational decision-making is utilised when the threshold is increased and could be reached by an optimal amount of information. In summary, different levels of rationality are required to make each decision depending on varying levels of task importance (Curley et al., 2019).

In the field of healthcare, decision-making plays a vital role in clinical practice, specifically in diagnosis and treatment planning. The process of making healthcare decisions is often complex, involving the integration of individual clinical expertise with the best available clinical evidence, together with patient's predicaments, rights, and preferences (Sackett et al., 1996). Similarly, in dentistry, these three aspects should be combined to develop an appropriate treatment plan. These include the patient's treatment needs and preferences, the best

available scientific evidence, and the dentist's clinical expertise. Decision-making in dentistry can be seen particularly in the diagnostic process, treatment plan consideration, and preventive strategy design. Many healthcare decisions are based on system 1 of the dual process theory. The system is fast, frugal, requires little effort, and frequently gets the correct answer. Nevertheless, it fails occasionally, sometimes catastrophically. It is often used when the situation is simple or recognisable (Croskerry, 2009). In contrast, system 2 is analytical, slow, and resource intensive, but more likely to acquire the right diagnosis. It is engaged when the situation is not readily recognised or does not follow a particular pattern. In diagnostics, if an illness presentation is recognisable, system 1 is often utilised, using intuition and experience. Unrecognised presentation often triggers system 2, which requires rationality, logical competence, and critical thinking in order to generate a decision (Croskerry, 2009). Furthermore, the system 2 could be supported by evidence-based dentistry (EBD), which has become more popular in clinical dentistry. EBD provides an approach to oral healthcare that follows a process of systematically collecting and analysing scientific evidence (Ismail et al., 2004). It has been highly suggested that dentists must utilise rationality with the tools of logical reasoning, critical thinking, and problem-solving (Elangovan et al., 2018). Additionally, investment in clinical research and education is necessary in order to evaluate the best currently available evidence and identify new information needed for better dental care (Ismail et al., 2004). However, a high-quality, evidence-based solution is not available for every clinical problem. So, there is still a big room for intuition-based decisions, which are supported by critical thinking, logical reasoning, and biological plausibility (Elangovan et al., 2018). This statement confirms the existence of a unified threshold model of decision-making where rational and intuitive approaches are both required in clinical decision-making process.

Three main factors that influence decision-making in dentistry are clinical guidelines and evidence-based practice, the dentist's experience and expertise, and the patient's needs and preferences (Elangovan et al., 2018; Ismail et al., 2004; Croskerry, 2009). Firstly, it is clear that all healthcare professionals should become lifelong learners by updating their knowledge and skills to the currently available evidence (Elangovan et al., 2018). Secondly, each dentist may have different experience and expertise, which influences their decision-making process. It

was noted that the level of training impacts the treatment decisions of dental care providers (Glassman et al., 2009). Additionally, the level of uncertainty tolerance can affect the behaviours of healthcare professionals, especially when making decisions. For instance, the willingness to recommend and utilise new medical interventions was more likely to be seen in healthcare providers with high uncertainty tolerance (Strout et al., 2018). Finally, autonomy of the patient should not be ignored. A shared decision-making process should be implemented, including incorporating the patient's values and preferences into the decision (Legare & Witteman, 2013; Geddis-Regan et al., 2024c). According to a classic article, shared decision-making was believed as an ideal model for making decisions in medical plans, which can decrease the informational and power imbalance between doctors and patients. The best practice of shared decision-making should involve both healthcare professionals and patients. Both sides need to share information and discuss their preferences until the agreed treatment is reached (Charles et al., 1997).

Despite following the major considerations in the decision-making process, a decision in some situations could be exclusively difficult if there is a conflict between the principles of medical ethics, which include autonomy, beneficence, non-maleficence, and justice (Gillon, 1994). There is no one correct answer for this ethical issue, but it depends on an individual case-by-case basis. Besides, the health service system can play another role involved in decision-making in dentistry. For example, a study in Scotland showed that a significantly higher number of patients in the hospital with an on-site GA service were referred for oral minor surgery, compared to another hospital without a GA facility (Sammut et al., 2013).

Decisions in dentistry can be made simpler in the general population, involving only a few factors, such as dental diagnosis, dentist skills and experience, resources, patient's willingness, time, and agreed cost of treatment. However, in SCD, this decision can be more complicated because the decision must take into account the multiplicity of modifying factors, including, but not limited to, the patient's socioeconomic status, psychological and medical problems, side effects of their medications, cumulative effects of dental diseases, and iatrogenic effects on the dentition due to previous dental care (Ettinger et al., 2021). It was reported that

undergraduate learning in SCD is often lacking (Faulks et al., 2012), which forces the dentists involving in the field to develop their skills through their motivations, observations, trials and errors, and their own experiences (Mac Giolla Phadraig et al., 2020b). Ettinger et al. (2021) also proposed a rational treatment planning in order to support decision-making in dental treatment planning for older adults, which conforms to the system 2 of the dual process theory (Ettinger et al., 2021). However, it may not be straightforward, especially in people living with cognitive impairment. For example, people living with dementia may have limited capability to understand and retain their autonomy once the disease progresses. Additionally, they reported that they often felt misunderstood and excluded from discussions or decisions about their dental care (Geddis-Regan et al., 2024c). Therefore, the final important point of decision-making is to involve the person themselves. Their own experiences of life, needs, likes, and also dislikes should be respected. It is imperative that decision-making in SCD should involve the patients themselves in order to promote courtesy and respect. Although this may not be possible in some cases with profound disability, healthcare professionals should still be kind and reassuring, avoid scolding or criticising, and respect their privacy (Dougall & Fiske, 2008b).

In summary, decision-making in dentistry is a complex and multifaceted process that requires balancing scientific evidence, clinical expertise, patient preferences, and ethical considerations. As the field of SCD continues to evolve, the integration of decision-making science into clinical practice will become increasingly important. Clinical decision-making process in this cohort requires further support for better patient outcomes and satisfaction. Future research should focus on developing more sophisticated decision support tools and exploring the impact of decision-making processes on clinical implications.

2.3 Previous Supporting Tools, Models, or Studies in the Use of Treatment Adjuncts in SCD

In dentistry, there are a number of tools or models to support treatment planning, but very few in Special Care Dentistry. There are several tools assisting in other dental specialties. For example, in endodontics, the Endodontic Case Difficulty Assessment by the American Association of Endodontists (Simon, 1999) can help with the treatment planning of teeth requiring endodontic treatment. The assessment tool can guide the level of the operator who is suitable to perform the endodontic procedure of a particular case. A significant benefit, such as a reduced number of complications and visits, was shown when using the tool for educational purposes (Almohaimede et al., 2022). The Index of Orthodontic Treatment Need (IOTN) was developed in 1989 (Brook & Shaw, 1989). The IOTN has been helpful in differentiating treatment eligibility according to different levels of providers, such as general dentists, orthodontic specialists, and consultants in orthodontics (Cousley, 2013).

In SCD, most of the established tools can be divided into two groups according to their primary objectives of the tools, either for diagnosis/assessment or treatment planning.

1. Complexity assessment tools

Firstly, a widely used tool to assess case complexity in SCD is a series of Case Mix Tool. It was first developed by the British team as '*the BDA case mix tool* or *BDA-CMT*' (Bateman et al., 2010). Patients are evaluated and scored in six domains, including ability to communicate, ability to cooperate, medical status, oral risk factors, access to oral care, and legal and ethical barriers to care. There is an adapted version called *'the simplified case mix tool* or *sCMT'* which consists of five domains by removing the oral risk factors from the original model (Duane et al., 2014).

In France, there was a need to initiate a tool to identify the degree of adaptation necessary for the provision of dental care for patients requiring SCD. The *French Case Mix Tool* (French-CMT) has been then developed and validated (Faulks et al., 2023). Seven domains were considered in the French-CMT, including (1) communication, (2) need for sedation, GA, or

other facilitatory techniques, (3) cooperation, (4) medical health, (5) dental risk factors, (6) autonomy, (7) medical administrative coordination. Currently, the iADH is currently working on the development of an Universal Case Mix Tool because the implications of the tool may require a certain degree of adaptations due to different intentions to use the tool and local cultural backgrounds and services in various countries (Bogner et al., 2024).

Apart from the series of CMT, there were two more tools to assist in assessment and planning for geriatric patients. Firstly, the Seattle Care Pathway is one of the most popular methods to define different levels of dependency of older adults. Several clinical scenarios were used to classify five categories of the pathway. They used, for example, physical health, chronic disease, oral health impacts, and levels of help needed to access dental services (Pretty et al., 2014). Moreover, OSCAR is a geriatric dental assessment tool. In 1994, another geriatric dental assessment tool, entitled OSCAR, was developed to systematically help generate oral care plans for older adults. The OSCAR tool is an acronym for Oral, Systemic, Capability, Autonomy, and Reality (Shay, 1994).

2. Treatment planning tools

Newton et al. (2012) outlined some possible approaches based on the level of dental anxiety. They suggested the use of non-pharmacological behavioural support techniques in patients with low level of dental anxiety, including rapport building, voice control, distraction, modelling, memory reconstruction, and environmental adaptation. In moderately anxious patients, an addition of preparatory information should be employed. Three aspects of preparation should inform what will happen, what to expect and feel, and what to do to cope with the situation. Lastly, cognitive behavioural therapy (CBT) should be added in the patients with high level of dental anxiety, as well as pharmacological management, such as conscious sedation and GA (Newton et al., 2012).

Coulthard, in 2013, introduced a tool called the Indicator of Sedation Need (IOSN), which was designed to help clinical decision-making regarding the need to use conscious sedation. It was developed mainly for patients with dental anxiety, which showed that at least 5% of the general population required conscious sedation for their dental treatments (Coulthard, 2013).

It involves three principal factors: anxiety score, medical and behavioural indicator score, and treatment complexity score. The anxiety score is converted from the Modified Dental Anxiety Scale (MDAS) (Humphris et al., 1995). The section on medical and behavioural indicator scores can be rated high if the patient, for example, has systemic diseases, learning disability, or gag reflex. The treatment complexity score depends on the planned dental treatment and can be given from one (routine treatment) to four (highly complex treatment). Any form of conscious sedation is needed if the sum score from the three domains is seven or higher. A score of ten to twelve indicated a very high need for sedation and may require GA instead (Coulthard, 2013). However, it was reported unsuitable to be a direct 'yes or no' commissioning tool because it relies too much on the MDAS score, which can be subjective to the patient and can have limitations to be used in patients with learning disability or dementia. It may easily lead to underestimating or overestimating the use of sedation in many situations (Shokouhi & Kerr, 2018).

Recently, a scoring tool has been developed to help decision-making in indicating GA for uncooperative children, called the SCAN-score or Score based on Child's behaviour, Age, and Need. It had four scoring domains: age, need for care, behaviour, and extra areas to be concerned. The details of the SCAN-score are shown in Table 4. GA was advised if a sum score from all domains was equal to or over ten. During the validation process, the SCAN-score was shown to effectively differentiate between the patients requiring GA and those who can be managed without GA ($p<0.05$). It had a sensitivity of 0.99 and a specificity of 0.94, with an Area under the Curve (AUC) of 0.99. The tool could be a promising support when deciding whether GA is needed in paediatric dentistry, especially for pre-school children with early childhood caries (Berat et al., 2024).

Table 4: the SCAN-Score

Domains	Description	Score
Age	6-7 years	1
	5 years	2
	4 years	3
	3 years and under	4
Need for care	1 sextant	1
	2 sextants	2
	3 sextants	4
	4 sextants or more	5
Behaviour	Dental anxiety / Reluctant during care	3
	Able to do clinical examination only	5
	Absence of cooperation for clinical examination	6
Extra areas	Communication barriers due to disability or language	3
	Care on permanent teeth needed	1
	Contraindication to local anaesthesia	9

In Spain, the PREdictors of Behaviour in Dentistry or PREBED model has been digitally developed to predict the need of GA for patients with intellectual disability. Data from 250 patients were collected, including those with intellectual disability of unknown origin, down syndrome, autism spectrum disorder, cerebral palsy, and some rare diseases. They found that behaviour during a dental examination had a significantly positive relationship with several routine behaviours and behaviours in other medical areas, based on the Frankl scale. These were behaviour during haircut, nail trimming, and tooth brushing, as well as behaviour when having a blood test, taking an extraoral radiograph, and having an electrocardiogram test. Furthermore, they found that the need to use GA for dental treatment was associated with noise and vibration intolerance, behaviour when shaving/depilating, behaviour during tooth brushing, and behaviours when going to have a blood test, an extraoral radiograph, and an electrocardiogram. Then, they algorithmically developed the PREBED model from their inputs.

Eighty patients were conveniently selected for a validation process, which revealed an accuracy of 63% - 76% in predicting the need for performing dental treatment under GA (Varela et al., 2021). The authors concluded that their results of the PREBED model could encourage the exploration of other potential factors affecting the decision in treatment planning for individuals with intellectual disability.

In order to support the shared decision-making system, a decision aid for young patients (10-16 years old) and their parents/guardians was created to support the selection of treatment modalities between inhalation sedation, IV sedation, and GA. It consisted of twelve questions related to the procedures of each treatment modality and their associated risks, benefits, and side effects. Each question asked how important each situation/statement is to the patient, and it can be scored from zero (not important) to five (very important). Example questions were how important to be awake when you have treatment, how important to avoid having a needle in your hand or arm, how important to avoid the needle in the gum, how important to be able to go straight back to school afterwards, and how important to have fewer appointments. It showed that the decision aid could be beneficial to both patients and their parents/guardians when facing the decision to undergo dental treatment under sedation or GA through increased knowledge of the available choices (Hulin et al., 2017).

In summary, each treatment modality has its characteristics, indications, contraindications, benefits, impacts, and risks of adverse events. Hence, the decision-making process of selecting an appropriate modality is varied and complex. Unfortunately, most published guidelines do not consider people with special needs (Glassman, 2009). Only a few tools explore this challenging issue, most of which were around the implications of GA or specific to paediatric patients. None explored the prediction of treatment modality in patients requiring SCD in the context of four different treatment modalities available, including routine, inhalation sedation, IV sedation, and GA. Therefore, there is a strong need to find out the current understanding of the decision-making in treatment adjunct selection for patients requiring SCD. Hopefully, the data from the study can establish a supporting tool to assist in better treatment planning in the future, which can give several benefits to patients, dentists, and the environment.

Patients can benefit from, for instance, decreased waiting time for treatment by not unnecessarily sitting on the wrong waiting list, reduced fear and anxiety exacerbated by the failure of treatment under the wrong adjunct, and increased trust in dentists and dentistry. For dentists, duplicated administration and clinical work and work-related stress can be lessened while developing better patient-dentist relationships (Geddis-Regan et al., 2024b). Finally, being more accurate in treatment adjunct prediction could promote environmental sustainability in terms of efficient resource utilisation and reduction of wastes produced from unsuccessful clinical sessions (Mac Giolla Phadraig et al., 2022a). Overall, here is our core rationale, which led us to commence this study.

3. Aims, Objectives, and Research Questions

The study aims to develop a better understanding of the predictability of treatment adjuncts in Special Care Dentistry (SCD) in terms of accuracy and also the factors associated with the unsuccessful selection of the optimal adjunct. In order to achieve this aim, a pilot study *(Appendix A)* was set up to test the feasibility of the planned methods prior to the commencement of the main study.

3.1 Pilot Study

Objective: To assess the feasibility of the planned investigation and develop the final project methods.

Research Questions:

a. Is the planned data collection process (data abstraction) feasible?
b. What can be done to improve the feasibility and validity of the data collection process?

The pilot study was performed prior to our main data collection process, with ethical permission to access a small number of charts *(Appendix B)*. Its aim was mainly to test the feasibility of the data collection process, including variable construction, collection, and analysis. The result had well informed the inclusion and exclusion criteria of the main study, a set of variables needed to be collected, and some modifications of data operationalization and abstraction. Details of the pilot study can be seen in *Appendix A*.

3.2 Main Study

Objective 1: To develop an understanding of the accuracy in predicting the correct adjunct use in a Special Care Dentistry clinic.

Research questions:

a. How accurate are clinicians in predicting the use of a successful adjunct?
b. Which factors predict accuracy when predicting the use of a successful adjunct?

Objective 2: To explore the accuracy of predicting the use of a successful adjunct across each adjunct for patients in Special Care Dentistry clinics.

Research questions:

a. How accurate, specific, and sensitive are clinicians when predicting the successful use of each predicted adjunct?
b. Which factors predict the successful adjunct use for each predicted adjunct?

4. Material and Methods

4.1 Design

This study adopts a retrospective chart review design. A protocol was developed a priori and followed accordingly. The design was aligned with guidance for the conduct and reporting of the retrospective chart review (Gearing et al., 2006; Vassar & Holzmann, 2013). A predefined protocol was followed throughout.

4.2 Ethical Considerations

4.2.1 Ethical Approval

In terms of ethical considerations, there were a number of areas to address prior to commencing this research project, including:

1. According to Trinity College Dublin's guidance, this research is considered 'no risk to relatively low risk' research, which requires approval by a level 1 research ethics committee.
2. Prior to the main study, special permission was granted by the Chair of the Dental School Research Ethics Committee (DSREC) to perform a pilot study via a limited exploratory review of a small number of charts in order to test the feasibility of the methodology and inform the full ethics application, dated 11th February 2022 *(Appendix B)*.
3. The design of the main study falls into category number 5 of the research requiring approval by a level 1 REC as "*Analysis of irrevocably anonymised and appropriately collected data, that the researcher has permission from the owner to access"*.
4. Ethical approval of the main study was granted to this study by the DSREC in January 2023 with the reference number DSREC01/2023 *(Appendix C)*.

4.2.2 Health Research Regulations (Consent)

This research was conducted in line with the Guidance on Retrospective Chart Review Amendment to the Health Research Regulations January 2021, Department of Health Services Executive (HSE) and the HSE National Policy for Consent in Health and Social Care Research (Health Service Executive, 2023).

Topic 6.8 on the HSE National Policy for Consent in Health and Social Care Research states that *"a retrospective chart review carried out for research purposes can be done without the consent of participants, subject to mandatory safeguards and specified governance mechanisms"*. The research must be low-risk and approved by an assigned research ethics committee before commencing. It was focused on the transparency arrangement of the data, which requires notices or posters on display in public areas where the patients attend healthcare services. It was confirmed within the ethics application that the DDUH displays posters indicating that personal data may be used for a retrospective chart review without personal identification when published. One of the posters was displayed at the waiting area of the West Clinic, where the SCD service takes place *(Appendix D)*.

4.2.3 Data Protection

Since the study involved the use of personal and sensitive data, the Data Protection Impact Assessment (DPIA) form was submitted with the ethical application form *(Appendix E)*. In order to comply with regulations, the principal investigator undertook an online Data Protection Training module, organised by the TCD, which complies with the Irish Data Protection Act 2018 and EU General Data Protection Regulation (GDPR) *(Appendix F)*.

4.3 Population and Sample

At Dublin Dental University Hospital (DDUH), the Special Care Dentistry (SCD) clinic is a secondary/tertiary dental specialist centre where all patients require referral by letter in order to be considered and accepted for assessment and treatment.

The stages of patient's pathway are listed below:

1. A referral letter was received by post or email. The referral letter should include the patient's identification (name, date of birth, address), the patient's medical background, and dental problems.

2. Triage of the letter by a specialist in SCD who 'accepts' or 'does not accept' the patient for an episode of care. If not accepted, a letter describing the reason for not being accepted is sent back to the referrer.

3. If accepted, the patient is offered an appointment for assessment. A dedicated assessment clinic runs typically once a month (eleven months yearly), consisting of ten to twelve new patients per clinic. Patients in pain are fast-tracked into other non-dedicated assessment clinics on an ad hoc basis if they cannot be accommodated into assessment clinics in a timely manner.

4. At assessment, patients requiring dental care are placed onto one of four waiting lists, according to the perceived need for various treatment modalities (adjuncts):

   a) Routine care waiting list
   b) Nitrous oxide sedation waiting list
   c) Intravenous Sedation waiting list
   d) General Anaesthesia waiting list

5. Patients who do not require specialist treatment and are not placed on the above lists are advised to return to be regularly seen by their local dentists. In these cases, a letter is sent to inform the referring person.

6. When they reach the top of the waiting list, each patient is called for the planned treatment with the planned treatment adjuncts/modalities. Some patients may be prioritised if urgent treatment is required whilst they are waiting.

7. After the completion of a treatment course using any of the treatment adjuncts above, patients are discharged from the DDUH and advised to return to their referring dentists.

4.3.1 Sampling Method

Initially, a total population sampling of a period of ten years was planned. Records were considered for selection consecutively in annual blocks, starting from the most recent year and moving backward to the previous year in order. Selection commenced with records from January 2021 to December 2021, then moving backwards to collect data from January 2020 through to December 2020. This system not only helped our systematic data collection but also acquired the most recent data first, which was likely to represent the current clinical situation, based on the updated clinical practice guidelines and literature and consistent staff operators.

Data were only collected if the first assessment visit was dated within the focused timeframe. Due to the nature of SCD clinical system, an assessment clinic for newly accepted patients is on the first Wednesday of the month, running around ten months per year. In each clinic, there are around ten to twelve patients booked for an assessment. Therefore, new patients are expected to be 100 – 120 cases yearly. Following the pilot study *(Appendix A)*, it was deemed feasible to collect data over two years: 2020 and 2021.

4.3.2 Sample Size

The sample size was calculated according to the accepted rule of thumb for regression analyses, whereby a minimum participant-to-variable ratio of 10:1 is recommended within a model (Peduzzi et al., 1995). Therefore, applying this rule of thumb *post hoc*, a minimum sample size of sixty records was required for our model, which included six independent variables.

4.3.3 Selection Criteria

Inclusion and exclusion criteria were refined throughout the pilot study. The final criteria are shown in Table 5. Inclusion criteria were set to select sequentially all new patients attending the SCD clinic for an assessment, to be allocated a proposed (predicted) treatment adjunct, and subsequently that they received a treatment session, to receive an actual treatment adjunct which could be identified on their clinical notes.

Table 5: Selection criteria

Inclusion criteria	Exclusion criteria
1. All new patients accepted to Special care dentistry clinic, DDUH during 2020-2021. 2. Patients who attended an assessment clinic and who had at least one episode of care at DDUH.	1. Patients whose data cannot be retrieved by the Salud dental programme. 2. Patients for whom a predicted or actual treatment adjunct cannot be identified. 3. Patients who did not attend DDUH for booked treatments using a predicted adjunct. 4. Patients who did not require treatment in DDUH in subsequent visits.

4.4 Data Abstraction

Data collection commenced upon the approval of ethical standards. Electronic data collection was chosen for its cost-effectiveness, minimal input error, and ease of centralising and accessing data (Gearing et al., 2006). The original data was accessed via Salud Dental Suite 2020.1.0 (Two-Ten Health Limited, Dublin, Ireland), which required a passcode for access. The data was then stored in the Microsoft Excel programme (Microsoft, the USA), with access limited to the principal investigator and the main supervisor, underscoring the trust and responsibility placed on these key individuals. A codebook was generated, and an access log was maintained.

4.4.1 Operationalisation of Variables

Blending multiple directed literature reviews and team discussions, an initial list of original variables planned to be collected into the programme was generated as per Table 6. These incorporated aspects of the patient, their systemic health and ability, their treatment needs, behaviour and anxiety, and dental history. These variables were then piloted and optimised through an iterative formative process during the pilot study. Details are provided below.

Table 6: Initial data operationalization

Variables	Data to be collected/grouped
A. Demographic	Code or initials, Gender, Age
B. Assessment appointment	- Record month and year of assessment visit - Record assessor names and their roles
C. Medical status	- Cardiovascular - Respiratory - Haematological - Endocrinological - Neurological - Congenital - Oncology
D. Type of disabilities	1. Physical 2. Sensory 3. Intellectual 4. Medical complex 5. Mental 6. Emotional 7. Social
E. SCD concerns	A – Access B – Behaviour C – Communication C – Capacity FEDS – Feeding, Eating, Drinking, Swallowing (Dysphagia)
F. Information from the referral letter	- Referring dentist (private/HSE) - Requested modalities - Urgency - Other details such as behavioural issue, etc.

Variables	Data to be collected/grouped
G. Waiting time	Record the duration between the assessment visit and the first visit of treatment
H. Dental anxiety level	Record the Modified Dental Anxiety Scale (MDAS)
I. Past adjunct for dental care	- Record past adjunct for dental care, if available - Record if the previously used adjunct provided successful or unsuccessful outcome.
J. Dental treatment complexity	- Record the planned dental treatment in details, such as fillings, extractions, scaling, root canal treatment
K. Treatment adjuncts - Predicted treatment adjunct - Actual treatment adjunct	1. Routine / Local anaesthesia (LA) / Non-pharmacological behavioural support 2. Inhalation sedation 3. IV sedation 4. General anesthesia
L. Accuracy	Compare between predicted and actual treatment adjuncts. If there was an agreement, record as 'accurate'. However, if there was a change, record as 'inaccurate' and summarise the reason of inaccuracy.
M. Treatment status	1. Completed 2. Incomplete
N. Remarks	Any other details, if available, such as clinical holding.

A. Demographic Data

Initially, only patients' initials, gender, and age were planned to be collected. The patient's initials were recorded as the first letters of name and surname, such as PK, instead of Panupol Kunasarapun. Gender and age were collected using the information on the front page of each patient's profile. The age was planned to be collected as the patient's age at the time of an assessment visit, but the age shown on the front page of the programme was the current age. Therefore, the patient's year of birth was

collected instead and converted to age by a Microsoft Excel formulation function. After the pilot study, a decision was made to add the patient's hospital number (DDUH number) into the collection table for error detection and avoidance of duplicate data entry. Lastly, the patient's county of residence was advised to be collected because it was believed that the distance from the living place to the hospital might affect the decision of treatment adjunct selection. The patient's address was collected from the Salud system according to the county. Then, they were re-grouped based on how far from Dublin city centre where the DDUH is located.

B. Assessment Appointment

Assessment appointment was recorded in month and year of the date of the visit. This record was mainly used for chronological exploration of raw data. Furthermore, timing at the assessment visit was used to explore the waiting time since the patient had been referred to DDUH.

The operator whose name was on the treatment record was assumed as an assessor. Initials or DDUH codes were recorded, as well as the role of the assessor whether he/she was a consultant, specialist, post-graduate student, or non-consultant hospital dentist (NCHD or house officer).

C. Medical Status

Underlying medical details of the patient can be acquired from the patient's note in the section of 'Questions' in the Salud dental programme with triangulation via the patient's treatment record, scanned medical questionnaire, and a referral letter.

Initially, a few groups of medical diseases were listed broadly as cardiovascular, respiratory, haematology, endocrinology, neurological, congenital, and oncology. Then, data abstraction was complex when initial data collection was performed in the pilot study. Therefore, evidence or guidelines were needed to support this section.

The international classification of diseases and related health problems (ICD-11) by the World Health Organization (World Health Organization, 2022) was used as a guidance. Version 02/2022 of the ICD-11 for Mortality and Morbidity Statistics, released in February 2022, was applied. Since there were over 25 categories of health conditions in the list, the decision was made to select some of all groups which should be commonly seen in this cohort, as detailed in Table 7.

Table 7: Summary of the ICD-11, WHO (version 02/2022) and decision relevant to the study

Group	Subgroup	Examples	Decision
1. Infection		Gastroenteritis, Colitis HIV/AIDS Tuberculosis Viral hepatitis	To use
2. Neoplasm		Neoplasm in any area of body Carcinoma in situ Benign, Malignant	To use
3. Blood		Anaemia Thrombocytopenia Splenomegaly	To use
4. Immune		Immunodeficiency Lupus erythematosus Systemic sclerosis	Not to use; To be added to ‘others’
5. Endocrine		Diseases of thyroid gland (hyperthyroidism, hypothyroidism) Diabetes mellitus Adrenocortical insufficiency	To use

Group	Subgroup	Examples	Decision
		Obesity or Overweight (nutritional disorder)	
6. Mental, Behavioural, Neurodevelopmental	6.1 Neurodevelopmental	Intellectual disability Developmental speech and language disorder Autistic spectrum disorder Developmental learning disorder Attention deficit hyperactivity disorder	To use
	6.2 Mental & behavioural	Schizophrenia Bipolar disorder Depressive disorder Post-traumatic stress disorder Anorexia nervosa Bulimia nervosa	To use
	6.3 Anxiety or Fear-related	Dental anxiety	To use
	6.4 Neurocognitive	Delirium Dementia (Alzheimer)	To use
7. Sleep-wake disorders		Insomnia	Not to use

Group	Subgroup	Examples	Decision
8. Nervous system		Multiple sclerosis Epilepsy or seizures Stroke Disorders of cranial nerves Reye syndrome Cerebral palsy	To use; with exclusion of neurodevelopmental and neurocognitive disorders
9. Visual		Impairment of visual functions Glaucoma Cataract	To use in sensory disorders
10. Ear		Hearing impairment Deafness	To use in sensory disorders
11. Circulatory system		Hypertension Heart diseases Cardiac arrhythmia Diseases of arteries Diseases of veins Valvular diseases Lymphadenitis	To use

Group	Subgroup	Examples	Decision
12. Respiratory system		Asthma Chronic obstructive pulmonary disease Bronchiectasis	To use
13. Digestive system		Self-induced lip trauma Oral lesions Odontogenic cysts Non-odontogenic cysts Xerostomia Dentofacial anomalies Gastro-oesophageal reflux disease Gastritis/Peptic ulcer Liver disease Inflammatory bowel diseases	Not to use; To be added to 'others'
14. Skin		Dermatitis Urticaria, Eczema	Not to use
15. Musculoskeletal & Connective tissue		Osteoarthritis Osteonecrosis	Not to use; To be added to 'others'

Group	Subgroup	Examples	Decision
16. Genitourinary		Female Male Prostate Kidney	Not to use; Kidney disease to be added to 'others'
17. Sexual health			Not to use
18. Pregnancy, Childbirth			Pregnancy to be added to others
19. Perinatal period			Not relevant
20. Developmental anomalies		Spina bifida Cleft lip and palate Trisomy 21, 13, 18	To added to neurodevelopmental
21. Not elsewhere classified			Not relevant
22. Injury and poisoning of external causes			Not relevant
23. External causes of morbidity and mortality			Not relevant
24. Factors influencing health status or contact with health services			Not relevant
25. Code for special purposes			Not relevant
26. Supplementary chapter			Not relevant

Lastly, to ensure the completeness of data, there was a free text box for indicating all existing medical diseases of the patients and the yes/no question for how stable the medical disease(s) is(are). Unstable conditions include but are not limited to, unstable epilepsy, unstable asthma, unstable angina, and recent myocardial infarction.

D. Types of Disabilities

According to the Joint Advisory Committee for Special Care Dentistry in 2003, there was a suggestion to have a classification of patients with disabilities into seven groups, which were physical, sensory, intellectual, medical, mental, emotional, and social disability (Dougall & Fiske, 2008a).

We, therefore, sought other evidence to support this data operationalisation, including the above WHO's ICD-11. At that time, there was a recently published textbook in SCD – A Practical Approach to Special Care in Dentistry by Pedro Diz Dios and Navdeep Kumar (2022) (Diz Dios & Kumar, 2022), which was beneficial to our classification; its table of contents is shown in Table 8.

Table 8: Grouping of SCD patients according to Diz Dios and Kumar's textbook

1. Physical disability	1.1 Cerebral palsy 1.2 Epilepsy 1.3 Muscular dystrophy
2. Cognitive impairment	2.1 Attention deficit and hyperactivity disorder 2.2 Autism spectrum disorders 2.3 Down syndrome
3. Sensory impairment	3.1 Visual deficit 3.2 Auditory deficit
4. Infectious diseases	4.1 Tuberculosis 4.2 HIV/AIDS 4.3 Viral hepatitis

5. Endocrine diseases	5.1 Diabetes mellitus 5.2 Hypothyroidism 5.3 Hyperthyroidism
6. Hepatorenal diseases	6.1 Hepatic cirrhosis 6.2 Chronic kidney disease & Dialysis
7. Bone diseases	7.1 Osteoporosis 7.2 Paget disease 7.3 Rheumatoid arthritis
8. Cardiovascular diseases	8.1 Arterial hypertension 8.2 Angina pectoris 8.3 History of myocardial infarction 8.4 Carrier of coronary pacemaker 8.5 Carrier of valvular prosthesis 8.6 Carrier of coronary stent
9. Respiratory disease	9.1 Chronic obstructive pulmonary disease 9.2 Asthma
10. Bleeding disorders	10.1 Haemophilia 10.2 Treatment with heparin 10.3 Treatment with warfarin 10.4 Treatment with direct oral anticoagulants 10.5 Treatment with antiplatelets
11. Blood dyscrasias	11.1 Thalassaemia 11.2 Sickle cell anaemia 11.3 Neutropenia 11.4 Thrombocytopenia 11.5 Leukaemia 11.6 Lymphoma 11.7 Bone marrow transplantation

12. Immunosuppression	12.1 Systemic corticosteroids 12.2 Antineoplastic agents (chemotherapy) 12.3 Immunosuppressants (Solid organ transplantation)
13. Head and neck cancer	13.1 Surgery 13.2 Radiation therapy 13.3 Oral cancer survivor
14. Neurological disorders and strokes	14.1 Alzheimer disease 14.2 Parkinson disease 14.3 Multiple sclerosis 14.4 Motor neuron disease 14.5 Stroke
15. Psychiatric disorder	15.1 Anxiety and phobia 15.2 Depression 15.3 Schizophrenia 15.4 Recreational drug use 15.5 Alcoholism
16. Other special considerations	16.1 Allergy 16.2 Antiresorptive and antiangiogenic drugs 16.3 Pregnancy and breastfeeding 16.4 Bariatric patients 16.5 Homelessness 16.6 End of life

E. Special Care Dentistry (SCD) Concerns

At DDUH, there are five additional points to be concerned when providing care for people with disabilities. The 'five SCD concerns' were put as operationalised variables in the study. Those are:

A – Access
B – Behaviour
C – Capacity / Consent
C – Communication
FEDS – Feeding, Eating, Drinking, Swallowing

Generally, all patients in the SCD clinic have these SCD concerns recorded in the section of 'Special Care Dentistry Questionnaire' and the patient's treatment record. The SCD concerns can also be confirmed in a waiting list form where there are questions relating to access, behaviour, and consent/capacity.

F. Information from the Referral Letter

As the SCD clinic, DDUH is a secondary/tertiary dental care provider, and all patients must be referred for services. Information from the referral letter is definitely important in terms of, for example, the patient's medical background, previous dental history, attempt and failure of dental procedures, and urgency.

Information that needed to be recorded included the referring person/body, urgency of treatment, requested modalities or treatment adjuncts, and other important notes. The referring person/body can be an HSE dentist, a dentist from a private practice, a GMP/doctor, residential care, a disability centre staff, a patient self or family, DDUH internal referral, and others. DDUH internal referrals included referrals from the Accident & Emergency (A&E) clinic, consultants from other specialities, NCHDs in Irish Prisoner Services, and a referral made by Professor Alison Dougall for patients from the National Coagulation Centre, St James's University Hospital and Dental department, St Vincent's University Hospital. Urgency of care was defined as urgent if

the referring person/body mentioned pain, infection, swelling, or any conditions that implied the need for an urgent assessment appointment. It was also recorded if the patient had been suggested the use of sedation or general anaesthesia or the need for a hospital setting to provide dental care for the patient.

Mostly, 97.17 % of patients (n=103) had their referral letters scanned and uploaded to the Salud dental programme. Due to the limitation of the retrospective design, there were a few missing pages or parts of the page when scanning and uploading, whereas three patients had no referral letter stored in the programme.

G. Waiting Time

Waiting time, as defined in this study, is the duration from the date on a referral letter to the assessment visit date. It is crucial to note that this waiting time could potentially influence the success or failure of the treatment plan with the chosen treatment adjunct. This underscores the urgency of addressing any delays in the referral process.

H. Dental Anxiety Level

Dental anxiety may play an essential role in choosing the proper treatment adjunct. According to the literature, conscious sedation or general anaesthesia can aid people with severe dental anxiety (Newton et al., 2012). The Modified Dental Anxiety Scale (MDAS) is one of the most commonly used tools to assess a level of dental anxiety (Humphris et al., 1995). It was also used in the SCD clinic. However, after a pilot study, there was poor compliance in recording MDAS. Therefore, the level of dental anxiety was not adequate to be analysed in a final model.

I. Past Adjunct Use for Dental Care

The patient's previous dental history, which can be retrieved from a referral letter or a treatment record, is of utmost importance. Past adjunct use for dental care was recorded if the patient had been treated with or without treatment adjuncts. Even if a previous treatment adjunct failed to achieve successful treatment, it was noted to highlight the significance of this factor, which may potentially impact the treatment adjunct planning.

J. Details of Dental Treatment Plan

The dental treatment plan was collected from the record at an assessment visit and the plan in a waiting list form. The dental treatment plan was collected in detail, including whether it was a plan for tooth debridement or scaling, restorations, extractions, fissure sealants, removable prosthesis, fixed prosthesis, root canal treatment, and other any other treatment required. The collected details could then inform how complex the plan was.

K. Dental Treatment Complexity

In order to assess treatment complexity in dentistry, there are some supporting tools/checklists/guidelines for specific dental specialities. For example, the AAE Endodontic Case Difficulty Assessment has been made by the American Association for Endodontists to assess the complexity of endodontic cases (Simon, 1999) and the Index of Orthodontic Need has been made to evaluate the difficulty of orthodontic treatment (Brook & Shaw, 1989). On the other hand, there is an absence of any universally accepted measure of treatment complexity in special care dentistry. This may be because the nature of special care dentistry covers a broad range of dental care for people with disabilities or those who need additional care.

Units of Dental Activity (UDAs) was chosen for this data abstraction. The UDAs has been created by the National Health Service (NHS) England (National Health Service England, 2023). It divides dental works into three major bands based on their

complexity. Band 2 can be subdivided into subgroups a, b, and c. Each band has a different score.

The dental treatment plan was acquired from either an assessment note or a waiting list form. The summative score of UDAs was used as *'dental treatment complexity'* in this study. Details of UDAs and its scoring can be seen in Table 9. Total UDAs scores were then categorised based on the volume of treatment and divided into low, moderate, or high dental complexity.

Table 9: Example treatments and scoring based on the Units of Dental Activity

Band	Example treatments	Score
1	Examination Preventive measures, such as fissure sealant (per tooth)	1
2a	Scaling (per mouth) Filling (per tooth) Extraction (per tooth)	3
2b	Non-molar root canal treatment (per tooth)	5
2c	Molar root canal treatment (per tooth)	7
3	Fixed prosthodontics (per crown/abutment) Removable prosthodontics (per arch)	12

L. Treatment Adjuncts (Predicted Treatment Adjunct and Actual Treatment Adjunct)

Treatment adjuncts acted as both dependent and independent variables in this study, depending on the objectives of different research questions. Four main treatment adjuncts were set up according to four main different waiting lists, which are:

1. Routine setting (local or non-pharmacological setting)
2. Inhalation sedation (nitrous oxide sedation)
3. Intravenous sedation (IV sedation with midazolam)
4. General anaesthesia (GA)

In this thesis, the term 'routine setting' may be used interchangeably with 'regular setting', 'local setting', 'local anaesthesia', or 'non-pharmacological behavioural support'. 'Inhalation sedation' is also similar to 'nitrous oxide sedation' or 'nitrous oxide and oxygen', or 'gas sedation'. Midazolam is a sole agent used in IV sedation in our practice. Oral sedation may sometimes be planned prior to IV sedation to promote anxiolysis and allow safe cannulation. Oral sedation with midazolam is performed only when having a plan of IV sedation in place. Therefore, in this thesis, 'IV sedation' refers to a sedative method using intravenous midazolam, with or without pre-operative oral sedation with midazolam. Lastly, GA is in collaboration with an anaesthetic team in St Columcille's Hospital, meaning that once the patient is put on a waiting list for GA, the patient will be pre-operatively assessed by the anaesthetic team, either in-person or tele-consultation, prior to the GA visit.

- *Predicted Treatment Adjunct (Pre-TA)*

This was the chosen treatment adjunct in the treatment plan. Pre-TA can be primarily known by a record in a waiting list form, then this was confirmed with either an assessment note or treatment code.

- *Actual Treatment Adjunct (Act-TA)*

On the other hand, the actual treatment adjunct (Act-TA) is the successful treatment adjunct used over the course of treatment. If there were more than one successful Act-TA, the most restrictive one was recorded. In this situation, GA is the most restrictive treatment adjunct, followed by IV sedation, inhalation sedation, and routine setting. Physical restriction was not included in this study.

M. Accuracy

Accuracy was recorded as accurate or inaccurate when comparing Pre-TA with Act-TA. The unit of analysis was set at the case level rather than the visit level. If there was a

disagreement between Pre-TA and Act-TA, the treatment notes were reviewed in order to summarise the reason for the modification of the treatment adjunct.

N. Treatment Status

The entire treatment notes were comprehensively reviewed in order to explore the completion of the treatment course. The treatment status was categorised as 'completed' if explicit documentation indicated that the treatment was completed, the patient was ready to be discharged, or if their next appointment was scheduled for review in more than three months duration. If the course of treatment has not been finished yet, the treatment record was reviewed to explore how reliable the current treatment adjunct could be considered the Act-TA. If the Act-TA was believed to be unidentifiable, the record was excluded from the study.

O. Remarks

Any other information that did not fall into any of the above categories was noted in a remark, such as the need for clinical holding (low/medium/high level) and the use of oral sedation.

4.4.2 Final List of Operationalised Data and Abstraction

After the pilot study, final operationalised data is listed in Table 10 with coding for data abstraction.

Table 10: Final set of operationalised data and data abstraction

Category	Operationalised data	Recording details / Coding
A. Demographic data	DDUH number	Specific number in 7-digit system
	Initials	First letters of first and last name
	Age	Age at an assessment visit
	County of residence	1 = Dublin 2 = Meath, Kildare, Wicklow 3 = The rest of Ireland
B. Assessment appointment	Assessor	Record as DDUH Salud code
	Role of assessor	1 = Consultant 2 = SCD specialist 3 = Postgraduate student 4 = NCHD / House officer
	Assessment visit	Record month and year of the assessment visit

Category	Operationalised data	Recording details / Coding
C. Medical status	Neurodevelopmental	0 = None 1 = Intellectual disability 2 = Autism spectrum disorders 3 = Down syndrome 4 = Attention deficit and hyperactivity disorder
	Neurocognitive	0 = None 1 = Delirium 2 = Dementia, Alzheimer
	Nervous system	0 = None 1 = Cerebral palsy 2 = Multiple sclerosis 3 = Epilepsy or seizures 4 = Stroke 5 = Disorders of cranial nerves 6 = Reye syndrome 7 = Spinal cord injury 8 = Parkinson disease 9 = Huntington’s disease

Category	Operationalised data	Recording details / Coding
	Mental and behavioural	0 = None 1 = Schizophrenia 2 = Bipolar disorder 3 = Depressive disorder 4 = Post-traumatic stress disorder 9 = Unspecified psychiatric disorder
	Anxiety or Fear	0 = None 1 = Dental anxiety 2 = Generalised anxiety
	Cardiovascular	0 = None 1 = Hypertension 2a = Congenital heart disease 2b = Ischaemic heart disease 3 = Cardiac pacemaker, valvular prosthesis, coronary stent 4 = Peripheral vascular disease 5 = Valvular heart disease (no prosthesis)

Category	Operationalised data	Recording details / Coding
	Respiratory	0 = None 1 = Asthma 2 = Chronic obstructive pulmonary disease 3 = Bronchiectasis
	Haematological	0 = None 1 = Red blood cell disorders (anaemia, thalassemia, sickle cell anaemia) 2 = Coagulation defects (haemophilia, von Willebrand) 3 = White blood cell disorders (leukaemia, lymphoma) 4 = Platelet disorders (thrombocytopenia)
	Endocrine	0 = None 1a = Hypothyroidism 1b = Hyperthyroidism 2 = Diabetes mellitus 3 = Adrenal insufficiency
	Infection	0 = None 1 = HIV/AIDS 2 = Tuberculosis 3 = Viral hepatitis

Category	Operationalised data	Recording details / Coding
	Cancer	0 = None 1 = Cancer of head and neck region 2 = Other parts of body cancer
	Sensory deficit	0 = None 1 = Visual impairment (unspecified severity) 1a = Complete visual impairment 1b = Partial visual impairment 2 = Hearing impairment (unspecified severity) 2a = Complete hearing impairment 2b = Partial hearing impairment 3 = Sensory processing disorder
	Others	0 = None 1 = Autoimmune diseases 2 = Kidney disease 3 = GI and liver disease 4 = Bone diseases (osteoporosis) 5 = Allergy 6 = Pregnancy

Category	Operationalised data	Recording details / Coding
D. Types of disabilities	Physical disability	0 = No 1 = Yes
	Sensory disability	0 = No 1 = Yes
	Neurodevelopmental disorder	0 = No 1 = Yes
	Acquired neurological disorder	0 = No 1 = Yes
	Medical complexity	0 = No 1 = Yes
	Psychiatric/Emotional disorder	0 = No 1 = Yes – Disease 2 = Yes – Dental anxiety
	Social exclusion	0 = No 1 = Yes

Category	Operationalised data	Recording details / Coding
E. SCD concerns	Access	0 = No issue 1 = Treated on wheelchair (+/- tilting machine) 2 = Self-transfer from wheelchair 3 = Hoist transfer or transfer with lots of help
	Behaviour	0 = No issue 1 = Challenging behaviour
	Communication	0 = No issue 1 = Non-verbal 2 = Hearing problems 3 = Other communication problems
	Capacity	0 or 1 = No issue; Has capacity to consent 2 = Assent 3 = Requires case conference 4 = Ward of court
	FEDS	0 = No issue 1 = Percutaneous endoscopic gastrostomy (PEG) feeding 2 = Dysphagia 3 = Liquidised food

Category	Operationalised data	Recording details / Coding
F. Information from the referral letter	Referring person/body	1 = HSE dentist 2 = Dental private practice 3 = GMP, doctor 4 = Residential care 5 = Disability centre staff 6 = Self-referral from the patient or family 7 = DDUH internal referral 8 = Others 9 = No referral letter available
	Special request	0 = No 1 = Yes, for sedation/GA 2 = Yes, for tertiary care/specialist setting
	Urgency	0 = No 1 = Yes, urgent appointment advised
	Additional note	Record any other important information gained from the referral letter
G. Waiting time	Waiting time	Record, in a number of months, a duration between the date on referral letter and the assessment visit date.

Category	Operationalised data	Recording details / Coding
H. Dental anxiety	MDAS	Record MDAS level Record N/A if not available
I. Past adjunct use for dental care	Past adjunct use for dental care	Record, if available, previous history of adjunct used for dental care. Record 'failed' if the previously used adjunct was unable to facilitate successful treatment.
J. Details of dental treatment plan	Tooth debridement / Scaling	0 = No 1 = Yes
	Fissure sealants	Record a number of fissure sealants planned (tooth) Record 0 if none
	Restorations	Record a number of restorations planned (tooth) Record 0 if none
	Extractions	Record a number of extractions planned (tooth) Record 0 if none
	Removable prosthesis	Record a number of removable prostheses planned (piece) Record 0 if none

Category	Operationalised data	Recording details / Coding
	Fixed prosthesis	Record a number of fixed prostheses planned (unit) Record 0 if none Record 3 for a three-unit bridge
	Endodontic	Record a number of root canal treatments planned Record 0 if none Record separately for anterior and posterior teeth
	Other treatments	Specify any other treatment planned at an assessment visit, such as full mouth fluoride treatment with silver diamine fluoride (SDF)
K. Dental treatment complexity	Units of Dental Activity (UDAs)	Record UDAs according to the dental treatment plan, then convert into a summative score of UDAs. 1 = Low complexity (UDAs = 0-10) 2 = Moderate complexity (UDAs = 11-25) 3 = High complexity (UDAs is 26 or more)
L. Treatment adjuncts	Predicted treatment adjunct Actual treatment adjunct	1 = Routine 2 = Inhalation sedation 3 = Intravenous sedation 4 = General anaesthesia

Category	Operationalised data	Recording details / Coding
M. Accuracy	Accuracy	0 = Inaccurate (if Pre-TA did not match with Act-TA) 1 = Accurate
N. Treatment status	Treatment status	0 = Incomplete 1 = Complete
O. Remarks	Remarks for any other information	Open box to fill in any other details, such as clinical holding, oral sedation, etc.

4.4.3 Data Validation

Ensuring the quality of data abstraction is a crucial step in retrospective chart reviews. Therefore, a series of validation processes were put in place when retrieving data from records. As a first step, 10% of charts in the pilot study were meticulously validated independently by the primary supervisor. Any uncertainty and disagreement were explored through discussions for these charts and all other charts where extraction was uncertain, with scope for refining criteria and recategorising throughout.

All charts that met inclusion criteria during 2020 – 2021 were recorded in the data collection sheet. If the chart was excluded, only patient demographic data, assessment date, and reasons for exclusion were recorded. The reason of exclusion was recorded as one of the follows:

1. Patients whose data cannot be retrieved by the Salud dental programme.
2. Patients for whom a predicted treatment adjunct cannot be identified.
3. Patients who did not attend DDUH for booked treatments using a predicted adjunct.
4. Patients who did not require treatment in DDUH in subsequent visits.

As mentioned above, the patient's DDUH number was recorded only to support the data collection process proactively and prevent data duplication. A warning was set if a duplicated DDUH number was put into the column, and the cell was protected. After the completion of the data collection process, the DDUH number was deleted in order to anonymise the data, complying with the DPIA policy.

4.5 Data Management

Data management involved two software programmes: Salud Dental Suite 2020.1.0 (Two-Ten Health Limited, Dublin, Ireland) and Microsoft Excel (Microsoft Corporation, the United States).

The Salud Dental Suite is a software used in the DDUH. Access to the patient's chart is restricted to the DDUH staff or students only. Each chart was explored, and its data was extrapolated into the Microsoft Excel software. A data collection table was created for raw data. According to the DPIA, raw data can only be accessed by the principal investigator only. Then, data was pseudonymised prior to its analysis. The key for pseudonymisation was deleted once data analysis was completed.

4.6 Data Analysis

Details of data analysis are elaborated according to each research question.

Research question 1a: How accurate are clinicians in predicting successful adjunct use?

To answer the first question, a 4x4 confusion matrix was constructed for all four conditions with Predicted (Pre-TA) and Actual Treatment Adjuncts (Act-TA) tabulated on opposing axes. The matrix allowed for the calculation of accuracy through counts and proportions.

Moreover, every case that was identified as inaccurate was meticulously explored in detail to understand the reasons behind the treatment adjunct modification.

Research question 1b: Which factors predict accuracy when predicting successful adjunct use?

To identify variables that predict the accuracy of prediction across all adjunct types, the Statistical Package for the Social Sciences (SPSS) version 27.0 (SPSS Inc., the USA) was used to construct a multiple binary logistic regression. The mixture of variables was selected based on both theoretical and empirical selection. Accuracy of successful adjunct selection was used as a dependent variable. Theoretically derived independent variables were derived from a

discussion of the literature and practice within the research team. Statistically, bivariate correlations were calculated between the candidate independent variables and the dependent variable. When the p-value was less than 0.05 for bivariate correlation, these factors were brought forward into a multivariable binary logistic regression along with standard demographic data for controlling purposes. This process led to a regression model consisting of theoretically and empirically derived independent variables, with the accuracy of treatment adjunct selection as the dependent variable. Correlations between variables were reported using Odds Ratios (ORs), 95% Confidence Intervals (95%CI) of the ORs, and p-values. A significant level was set at p-value <0.05. The goodness of fit in logistic regression was calculated using Nagelkerke R Square statistics.

Research question 2a: How accurate, specific, and sensitive are clinicians when predicting the successful use of each predicted adjunct?

To answer this question, four 2x2 confusion matrices were tabulated, with one for each adjunct. Predicted (Pre-TA) and Actual treatment adjuncts (Act-TA) were tabulated on opposing axes. The matrices allowed for the calculation of accuracy, sensitivity, and specificity using proportions in predicting successful treatment adjuncts. Accuracy, sensitivity, and specificity were reported for each adjunct used in this study.

Research question 2b: Which factors predict successful adjunct use for each predicted adjunct?

The Posit Cloud (Posit, the United States), formerly known as R Studio, was used in an online format, available at https://posit.cloud/. A prediction model was generated using this online platform to predict Act-TA, using the classification tree method. The model was planned to have each end-point as the probability of each treatment adjunct to be successfully used, based on the conservative or less restrictive approach.

At first, the team applied an empirical approach to explore this research question. This led to an exploratory decision tree. Then, a number of literature, as well as practical clinical

approaches, were used to conceptualise which variables should be fed into the model. At this stage, some variables were recategorised in several ways to seek candidate models which have clinical relevance. The final model was chosen among the research team which possesses the best clinical significance, easy to practice, and simple to understand.

Furthermore, all variables were put into the Posit Cloud to generate a prediction model. This model had an end-point as four different actual treatment adjuncts in different probabilities. Models were run in a mixture of empirical and theoretical ways to find the most appropriate decision-tree model which has both significant level and clinical meaning. At this stage, some variables were recategorised in different ways to support the model. In the end, the discriminatory value of the final model was explored by using the receiver operating characteristic (ROC) curve and calculation of the Area Under the Curve (AUC). Programming codes can be seen in *Appendix G*.

5. Results

5.1 Case Selection

From January 2021 to December 2022, there were 163 new assessment cases in the SCD assessment clinic. According to the inclusion and exclusion criteria, 106 cases (65%) were included in the study. Fifty-seven cases (35%) were excluded. Among those, no further treatment required in the DDUH was the majority of exclusion (n=38, 66.67%). Inadequate information was another reason, which could be divided into unidentifiable predicted treatment adjuncts (19.30%) and unidentifiable actual treatment adjuncts because the patients did not attend DDUH for the planned treatment (14.03%).

5.2 Demographics

As per Table 11, of the 106 cases included in the study, 56 were male and 50 were female. The mean age at the assessment visit was 43.7 years old, ranging from 17 to 93 years old. Forty-four cases (41.5%) were adults from 17 to 35 years old, whereas 24 cases (22.6%) were over 60 years old. Two-thirds (n=71, 67%) of cases lived in county Dublin, 23.6% (n=25) resided in neighbouring counties Meath, Kildare, and Wicklow and were eligible for financial coverage by their governmental medical cards. Only ten cases (9.4%) had their registered addresses in the rest of the country.

According to referral letters, most patients (61.2%) were referred from private practices, followed by dentists in the Health Service Executive (HSE) (14.6%), general medical practitioners (11.7%), and DDUH internal referral (10.7%). Self-referral was accounted for two cases: one from the patient's family and another one from the patient's residential care staff. Urgency was flagged in 46 cases (44.7%) in the forms of "having pain", "infection", "swelling", or "needing urgent/emergency assessment". Any form of sedation or general anaesthesia was requested in 29 cases (28.16%), while 14 cases (13.59%) were requested to be assessed by an SCD specialist in a hospital setting. There were three cases (2.83%) in which the referral letters were irretrievable or illegible. Overall, the average duration between the date of referral letter acceptance and the date of assessment was 8.47 months. At assessment, over half of the cases

(55.66%) were assessed by post-graduate students/trainees in SCD, while 31 cases (29.25%) and 16 cases (15.09%) were done by consultant/specialist in SCD and non-consultant hospital dentist (NCHD / house officer), respectively.

Table 11: Demographics and referral details

Demographics and referral details		**Number of cases (n = 106)**	**Percentage of cases**
Age	17-35 years old	44	41.51%
	Between 35-60 years old	38	35.85%
	60 years old or older	24	22.64%
Gender	Male	56	52.83%
	Female	50	47.17%
Place of residence	Dublin	71	66.98%
	Meath / Kildare / Wicklow	25	23.58%
	Rest of the country	10	9.43%
Referring person	HSE dentist	15	14.15%
	Private dental practice	63	59.43%
	General medical practitioner	12	11.32%
	Residential care staff	1	0.94%
	Self-referral or family	1	0.94%
	DDUH internal referral	11	10.38%
	No referral letter identified	3	2.83%
Urgency [a]	Not urgent	57	55.34%
	Urgent	46	44.66%

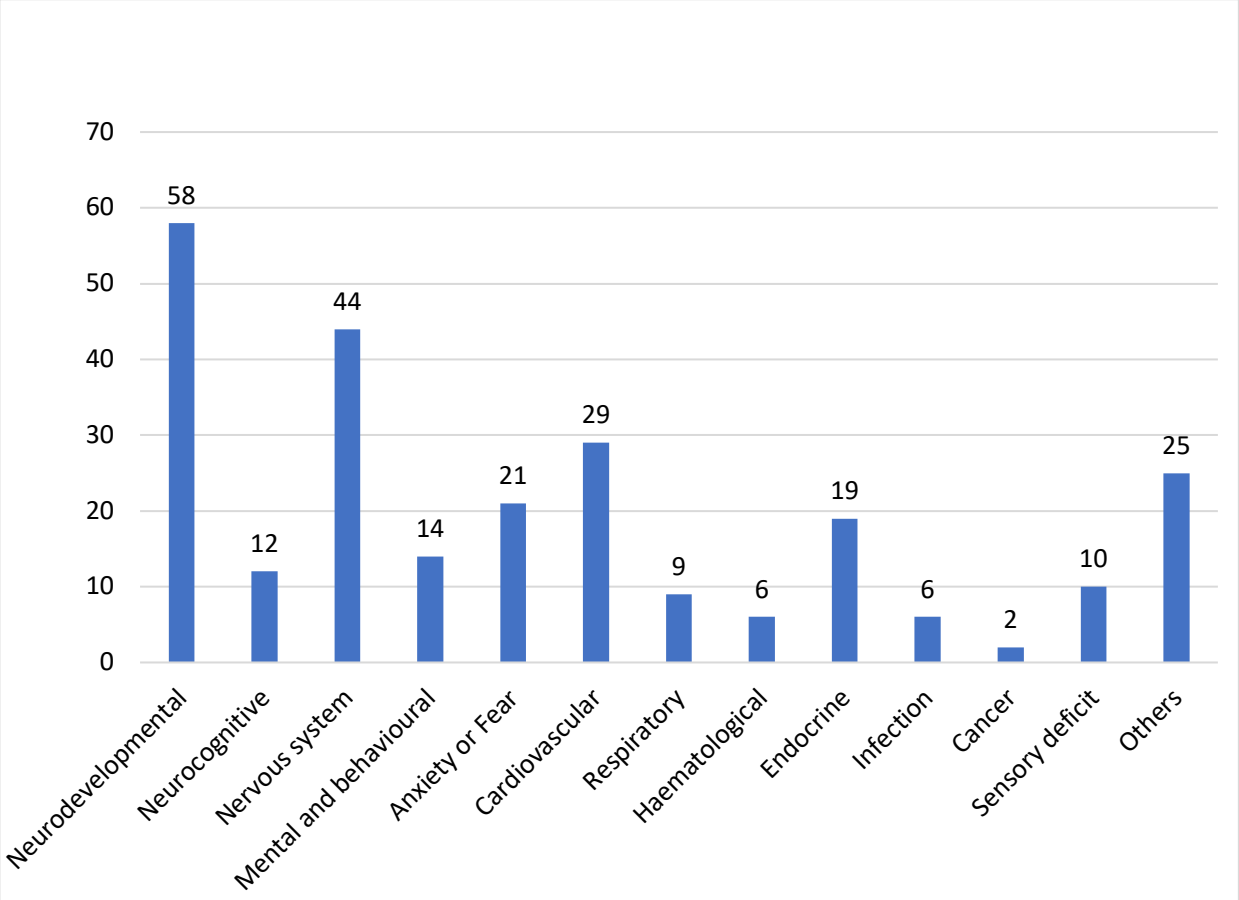
Past adjunct used for dental care	No history reported	61	57.55%
	Routine setting	21	19.81%
	Inhalation sedation	1	0.94%
	IV sedation	9	8.49%
	GA	14	13.21%
Success or failure of past adjunct	No history reported	61	57.55%
	Success	42	39.62%
	Failure	3	2.83%
Dental anxiety scale (MDAS) [b]	<9	3	9.09%
	10-18	12	36.36%
	19-25	18	54.55%
Assessor	Consultant / Specialist	31	29.25%
	Post-graduate trainee	59	55.66%
	House officer (NCHD)	16	15.09%

[a] Urgency n=103 cases (missing data = 3 cases)

[b] MDAS n=33 cases (missing data = 73 cases)

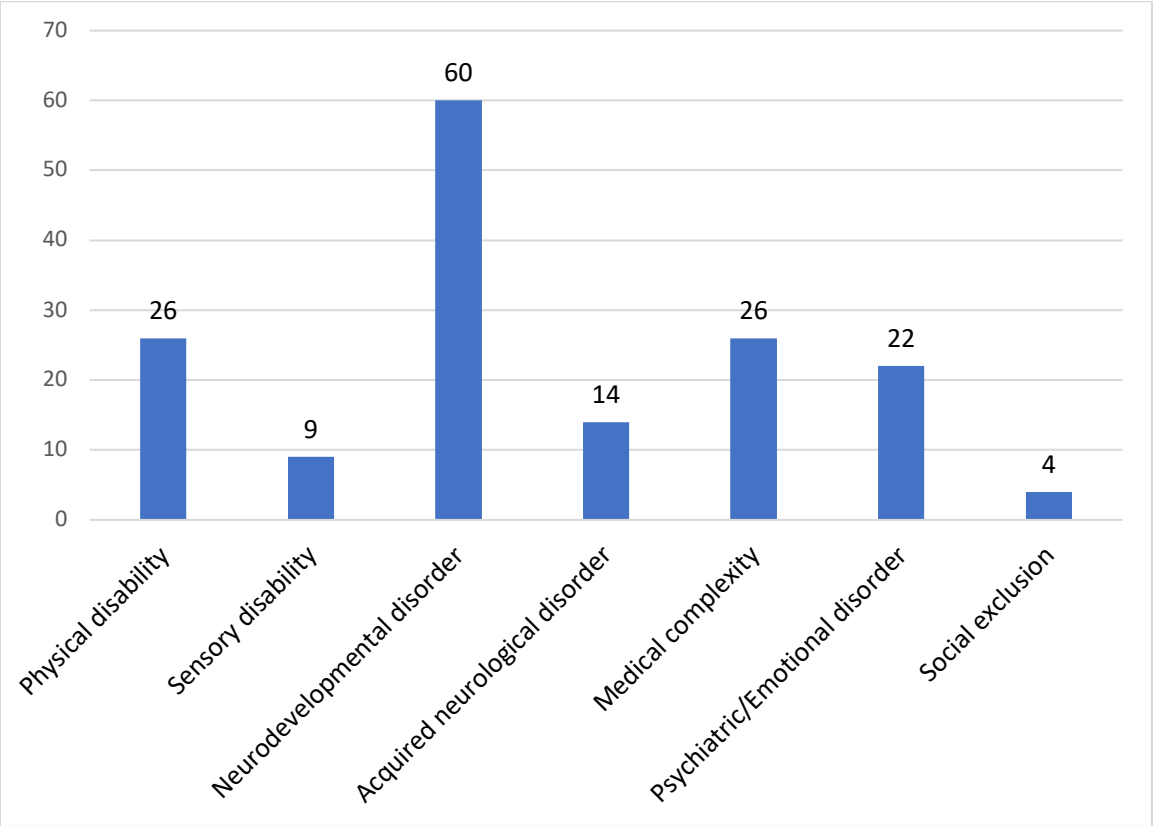
According to their medical background, the top three medical diseases in this cohort were neurodevelopmental, nervous system, and cardiovascular, respectively. A complete list of medical profiles is shown in Figure 1.

Figure 1: Number of patients according to their medical profiles



When looking at the most prevalent disability type of each individual, neurodevelopmental disability was the most prevalent group in included cases (n=58 cases, 54.72%), followed by physical disability and medical complexity, which share a similar number of cases (n=26 cases, 24.53%). Cases with psychiatric or emotional disorders, including those with dental anxiety, accounted for 22 cases (20.75%). Details of all types of disability are illustrated in Figure 2.

Figure 2: Number of patients according to their disability types



According to SCD concerns, 30.19%, 19.81%, 37.74%, 42.25%, and 14.15% had some issues in access, behaviour, communication, capacity, and FEDS, respectively. Thirty-two cases, in total, were wheelchair users, which could be divided into ability to self-transfer (6.60%) and inability to self-transfer, which required a wheelchair tilting chair or a hoist for transfer to a dental chair (23.59%). Challenging behaviour was reported in 25 cases (19.81%), which could be reported in a referral letter or during an examination. In this study, challenging behaviour was specified as behaviour that may be physically or emotionally harmful to the dental team or limits the ease of dental procedures. Hearing impairment was found only in four cases (3.77%), whereas non-verbal cases were noted in 31 cases (29.25%). Sixty-one cases (57.55%) had capacity to consent, while 45 cases (42.45%) were evaluated as lacking capacity, which required best interest, assent process, court decision, case conference, or mixture of these. Percutaneous endoscopic gastrotomy (PEG) feeding was found in two cases (1.89%). Modified diet due to feeding-eating-drinking-swallowing problems and dysphagia were reported in three cases

(2.83%) and ten cases (9.43%), respectively. Table 12 presented full information on SCD concerns in this cohort.

Table 12: Number of cases according to SCD concerns

SCD concerns		Number of cases (n = 106)	Percentage of cases
Access	No access issue	74	69.81%
	Wheelchair user, Able to self-transfer to dental chair	7	6.60%
	Wheelchair user, Treatment on wheelchair tilting chair, or required hoist for transfer	25	23.59%
Behaviour	No challenging behaviour reported	85	80.19%
	Challenging behaviour reported	21	19.81%
Communication	No communication issue	66	62.26%
	Expressive issue, such as non-verbal	31	29.25%
	Receptive issue, such as hearing impairment	4	3.77%
	Other communicative issues	5	4.72%
Capacity	Has capacity to consent	61	57.55%
	Lack of capacity	45	42.45%
FEDS	No FEDS issue	91	85.85%
	PEG feeding	2	1.89%
	Dysphagia	10	9.43%
	Dietary modifications due to FEDS issue	3	2.83%

Lastly, according to the modified dental anxiety scale (MDAS), which can quantify the level of dental anxiety, it was a big challenge to obtain information in this section because it was available in only 33 cases (31.13%). Among them, patients with severe dental anxiety (MDAS was 19-25) were the majority (n=18 cases, 54.55%), followed by some dental anxiety, MDAS was 10-18; n=12 cases, 36.36%) and little or no dental anxiety (MDAS was 5-9; n=3 cases, 9.09%).

5.3 Accuracy of Overall Treatment Adjunct Selection

When looking at the agreement between predicted and actual treatment adjuncts, there were 97 cases (91.51%) in which actual treatment adjunct use matched the planned adjunct and nine cases (8.49%) that did not match. Table 13 illustrates the number of treatment modalities selected and used to provide dental treatment during 2021 – 2022.

Table 13: Main finding of predicted and actual treatment adjuncts

		Actual treatment adjuncts			
		Routine	**N_2O**	**IV**	**GA**
Predicted treatment adjuncts	**Routine**	**48**	0	0	**1**
	N_2O	0	**5**	0	0
	IV	**2**	0	**22**	**5**
	GA	**1**	0	0	**22**

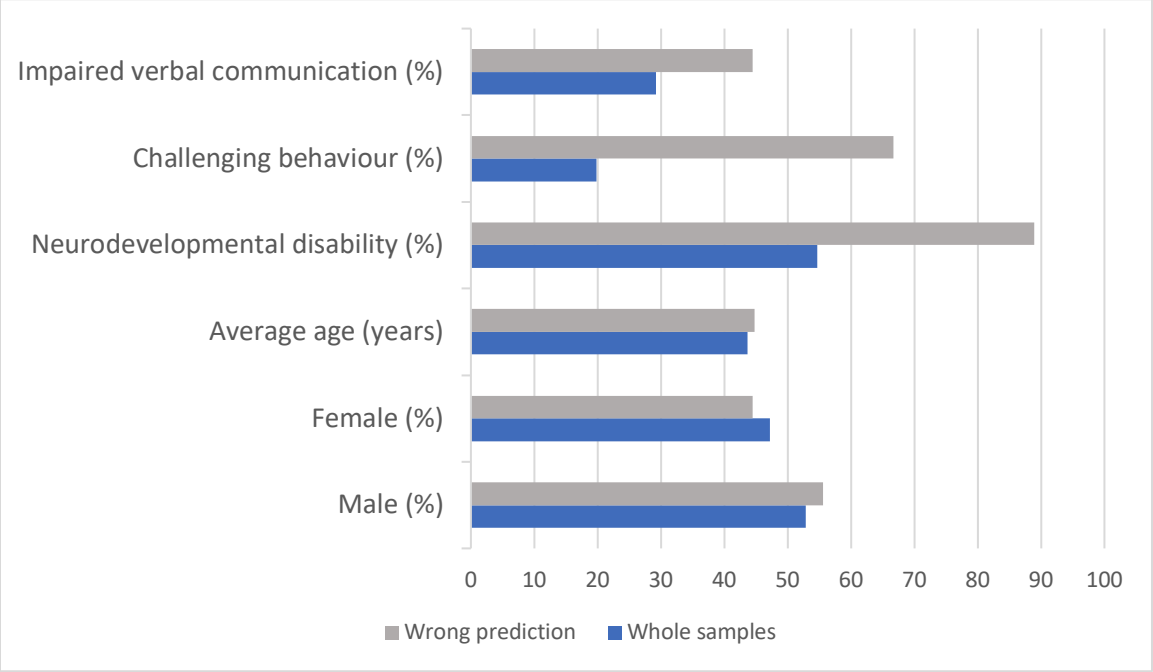
According to Table 13, the routine setting was selected in 49 cases in total; while it was successfully used for treatment in 48 cases (97.96%), one case encountered a cooperative issue, meaning that, ultimately, GA was used for a successful outcome for this patient. Of note, IV sedation was also attempted and was unsuccessful in this case. All inhalation sedation cases

were successfully treated as planned (n=5, 100%). Regarding IV sedation, 22 out of 27 cases (81.48%) were successfully treated according to the plan, but seven cases were shown to be unsuccessful, which required other modalities for appropriate treatments. Among 27 planned IV sedation cases, preoperative oral sedation with midazolam was planned in five cases. Lastly, 22 out of 23 cases (95.65%) were planned and successfully treated under GA, while another case had to modify the modality and treatment plan due to medical issues.

5.3.1 Exploring Inaccuracy

Exploring the nine cases with inaccurate prediction in detail, their age and gender distributions matched those of the overall sample, five males and four females. Their average age at assessment was 44.78 years old. Compared to the whole sample, a disproportionately high proportion of those whose predicted adjunct failed to be successful had neurodevelopmental disability (n=8 cases, 88.89% compared to a baseline proportion of 54.72%), challenging behaviour (n=6 cases, 66.67% compared to a baseline proportion of 19.81%), and impaired expressive communication (n=4 cases, 44.44% compared to a baseline proportion of 29.25%). Apart from those with neurodevelopmental disability, another case had acquired neurological illness. In terms of other SCD concerns, there were two cases, which were wheelchair users, one case with hearing impairment, five cases with incapacity, and one case who was on PEG feeding. Comparisons of demographics and characteristics between the whole sample and cases with wrong predictions are illustrated in Figure 3.

Figure 3: Comparisons between overall and inaccurately predicted cases



Reasons for treatment adjunct modifications can be grouped into three features:

1. Sedation Failure

Sedation failure is the most common reason for treatment adjunct modification. It was accounted for five cases (55.56%). Three cases were due to under-sedation, which leads to cooperative issues, while difficulty in venipuncture was the cause of failure in other cases. Among those with under-sedation, failure to drink an oral sedation prior to the cannulation was a major problem in one case. Two cases had the inadequate sedative effect of midazolam, with the decision to stop the sedation because of vital signs status. GA sessions were made for these under-sedated cases in order to complete the treatment. Interestingly, the decision was made to treat both cases with difficult venipuncture without sedation, which turned out to be successful.

2. Service Availability

Treatment adjuncts were modified because of service availability in three cases. The waiting list for each treatment adjunct has different waiting times. General anaesthesia was chosen instead of initially planned modalities because it was a quicker option and more arrangeable. It was a quicker choice for a patient who was on the IV sedation waiting list. In one case, it was arranged to assess and manage a patient who was in pain. Lastly, it was selected to manage another patient who had high dental treatment needs. Probably, a GA session would be completed quicker than a number of IV sedation sessions.

3. Medical Complexity

One patient was initially planned to have GA for receiving full dental treatment. However, the plan was changed after anaesthetic consultation. It was mainly due to extremely high body mass index (BMI) which could increase intraoperative risk. Therefore, the treatment adjunct was forced to be a non-pharmacological modality with a subsequent change in the dental treatment plan.

Furthermore, all nine cases were found to be involved with neurodisability, either neurodevelopmental disorder (n=8) or acquired neurological disorder (n=1). Among patients with neurodisability, treatment adjunct predictions were inaccurate in 13.85%. Statistically significant correlation ($p<0.05$) was confirmed by Pearson Chi-Square test, with p value of 0.031. Binomial logistic regression was unable to perform due to there was no case of inaccurate prediction who had no neurodisability.

5.4 Predictive Factor(s) for Accuracy of Treatment Adjunct Selection

A number of independent variables were selected based on a theoretical and empirical basis. Table 14 displays the number of cases in each independent variable with accuracy or inaccuracy in treatment adjunct selection. Pearson chi-square test of independence was used to explore the relationship between candidate independent variables and the accuracy of treatment adjunct prediction. Three independent variables revealed significant p-values ($p<0.05$), including urgency, neurodevelopmental disorder, and challenging behaviour. These variables were then brought forward into a multivariable binary logistic regression.

Table 14: Number of cases in each independent variable with accuracy and inaccuracy in treatment adjunct selection

		Inaccurate prediction		Accurate prediction		Chi-Square Tests		
		n	Column %	n	Column %	Value	df [b]	*P* value [a]
Gender	Male	5	55.6%	51	52.6%	0.03	1	0.86
	Female	4	44.4%	46	47.4%			
Age	17-35 years	4	44.4%	40	41.2%	1.03	2	0.60
	36-59 years	2	22.2%	36	37.1%			
	60 years and older	3	33.3%	21	21.6%			
Address (county)	Dublin	7	77.8%	64	66.0%	0.85	2	0.65
	Around Dublin area (Meath/Kildare/Wicklow)	1	11.1%	24	24.7%			
	Rest of the country	1	11.1%	9	9.3%			
Referring person	HSE dentist	0	0.0%	15	16.0%	4.02	5	0.55
	Private dental practice	8	88.9%	55	58.5%			
	General medical practitioner	0	0.0%	12	12.8%			
	Residential care staff	0	0.0%	1	1.1%			
	Self-referral or family	0	0.0%	1	1.1%			
	DDUH internal referral	1	11.1%	10	10.6%			

		Inaccurate prediction		Accurate prediction		Chi-Square Tests		
		n	Column %	n	Column %	Value	df [b]	*P* value [a]
Urgency [c]	Not urgent	1	11.1%	56	59.6%	7.81	1	0.01*
	Urgent	8	88.9%	38	40.4%			
Past adjunct used for dental care [d]	No history reported	2	22.2%	59	60.8%	2.71	3	0.44
	Routine setting	2	22.2%	19	19.6%			
	Inhalation sedation	0	0.0%	1	1.0%			
	IV sedation	1	11.1%	8	8.2%			
	GA	4	44.4%	10	10.3%			
Success or failure of past adjunct [d]	No history reported	2	22.2%	59	60.8%	0.77	1	0.40
	Success	6	66.7%	36	37.1%			
	Failure	1	11.1%	2	2.1%			
Dental anxiety scale (MDAS) [e]	<9	0	0.0%	3	9.7%	0.31	2	0.86
	10-18	1	50.0%	11	35.5%			
	19-25	1	50.0%	17	54.8%			
Assessor	Consultant / Specialist	2	22.2%	29	29.9%	0.66	3	0.88
	Post-graduate trainee	6	66.7%	53	54.6%			
	House officer (NCHD)	1	11.1%	15	15.5%			

		Inaccurate prediction		Accurate prediction		Chi-Square Tests		
		n	Column %	n	Column %	Value	df [b]	*P* value [a]
Physical disability	No issue	8	88.9%	72	74.2%	0.96	1	0.33
	Yes	1	11.1%	25	25.8%			
Sensory disability	No	7	77.8%	90	92.8%	2.39	1	0.12
	Yes	2	22.2%	7	7.2%			
Neurodevelopmental disorder	No	1	11.1%	45	46.4%	4.17	1	0.04*
	Yes	8	88.9%	52	53.6%			
Acquired neurological disorder	No	8	88.9%	84	86.6%	0.04	1	0.85
	Yes	1	11.1%	13	13.4%			
Medical complexity	No	8	88.9%	72	74.2%	0.96	1	0.33
	Yes	1	11.1%	25	25.8%			
Psychiatric or emotional disorder	No	8	88.9%	76	78.4%	0.78	2	0.68
	Yes - disorder	0	0.0%	6	6.2%			
	Yes – dental anxiety only	1	11.1%	15	15.5%			
Social exclusion	No	9	100.0%	93	95.9%	0.39	1	0.54
	Yes	0	0.0%	4	4.1%			

		Inaccurate prediction		Accurate prediction		Chi-Square Tests		
		n	Column %	n	Column %	Value	df [b]	*P* value [a]
Access issue	No issue	7	77.8%	67	69.1%	1.03	3	0.80
	Treated on wheelchair or a wheelchair tilting chair	2	22.2%	20	20.6%			
	Self-transfer	0	0.0%	7	7.2%			
	Transfer by hoist or lots of help	0	0.0%	3	3.1%			
Challenging behaviour	No issue	3	33.3%	82	84.5%	13.59	1	<0.01*
	Challenging behaviour	6	66.7%	15	15.5%			
Communication issue	Verbal	5	55.6%	70	72.2%	1.10	1	0.30
	Non-verbal	4	44.4%	27	27.8%			
Capacity issue	Has capacity to consent	4	44.4%	57	58.8%	0.69	1	0.41
	Lack of capacity	5	55.6%	40	41.2%			
FEDS	No issue	8	88.9%	83	85.6%	5.65	3	0.13
	PEG feeding	1	11.1%	1	1.0%			
	Dysphagia	0	0.0%	10	10.3%			
	Dietary modification	0	0.0%	3	3.1%			

		Inaccurate prediction		Accurate prediction		Chi-Square Tests		
		n	Column %	n	Column %	Value	df [b]	*P* value [a]
Dental treatment complexity (using UDA)	Low complexity	3	33.3%	54	55.7%	5.44	2	0.07
	Moderate complexity	6	66.7%	29	29.9%			
	High complexity	0	0.0%	14	14.4%			
Extraction planned	No	2	22.2%	41	42.3%	1.37	1	0.24
	Yes	7	77.8%	56	57.7%			
Number of extractions	None	2	22.2%	41	42.3%	2.62	2	0.27
	1-3 extractions required	7	77.8%	49	50.5%			
	4 or more extractions required	0	0.0%	7	7.2%			
Number of fillings	None	3	33.3%	56	57.7%	2.39	3	0.50
	1-3 restorations required	3	33.3%	25	25.8%			
	4-6 restorations required	2	22.2%	10	10.3%			
	More than 6 restorations required	1	11.1%	6	6.2%			

[a] *p* value was set at 0.05 * Statistically significant difference (p<0.05)

[b] degree of freedom

[c] Urgency n=103 cases

[d] Past adjunct used for dental care / success or failure of past adjunct n=45 cases

[e] MDAS n=33 cases

Multivariable binary logistic regression analysis was applied to assess the odds of predicting the accuracy of treatment adjunct prediction. Odds ratios (OR) and 95% confidence Intervals (95%CI) were generated, and alpha of 0.05 was adopted. Age and gender were put into the regression model, as well as three significant variables from the Pearson Chi-Square test. Variables were entered in order: gender, age, challenging behaviour, urgency, and neurodevelopmental disorder. Two variables revealed significant differences ($p<0.05$), which were challenging behaviour (OR = 0.10, 95%CI = 0.016 – 0.662) and urgency (OR = 0.06, 95%CI = 0.005 – 0.719). The regression model had Cox & Snell R Square of 0.19 and Nagelkerke R Square of 0.42, which indicated moderate fit. Table 15 shows a summary of the logistic regression of both unadjusted odd ratios and adjusted odd ratios, with their 95% confidence interval

Table 15: Logistic regression

	Accurate cases (%)	Inaccurate cases (%)	Unadjusted Odd ratios (95% CI)	P value of Unadjusted ORs	Adjusted Odd ratios (95% CI)	P value of Adjusted ORs
Gender						
Male	51 (91.07%)	5 (8.92%)	0.89 (0.23 – 3.50)	0.86	0.73 (0.14 - 3.97)	0.72
Female	46 (92%)	4 (8%)	1	<0.01	1	
Age						
17-35 years	40 (90.91%)	4 (9.09%)	1.43 (0.29 – 6.99)	0.66	0.78 (0.08 - 7.76)	0.78
36-59 years	36 (94.74%)	2 (5.25%)	2.57 (0.40 – 16.66)	0.32	2.59 (0.24 - 28.46)	0.44
≥ 60 years	21 (87.5%)	3 (12.5%)	1	0.61	1	0.55

	Accurate cases (%)	Inaccurate cases (%)	Unadjusted Odd ratios (95% CI)	P value of Unadjusted ORs	Adjusted Odd ratios (95% CI)	P value of Adjusted ORs
Challenging behaviour						
No	82 (96.47%)	3 (3.53%)	1	<0.01	1	
Yes	15 (71.43%)	6 (28.57%)	0.09 (0.02 - 0.41)	0.02	0.10 (0.02 - 0.66)	0.02 *
Urgency						
No	56 (98.25%)	1 (1.75%)	1	<0.01	1	
Yes	38 (82.61%)	8 (17.39%)	0.09 (0.01 - 0.71)	0.02	0.06 (0.01 - 0.72)	0.03 *
Neurodevelopmental disorder						
No	45 (97.83%)	1 (2.17%)	1	<0.01	1	
Yes	52 (86.67%)	8 (13.33%)	0.14 (0.02 – 1.20)	0.07	0.15 (0.01 - 1.80)	0.14

* Significant difference ($p<0.05$)

5.5 Accuracy, Sensitivity, and Specificity when Predicting Successful Adjunct Use for Each Predicted Adjunct

As per Table 16 – Table 19, four 2x2 confusion matrices were generated to explore the relationship between prediction and actual use for each adjunct. The accuracy and precision rates of each prediction are then summarised in Table 20, as well as their sensitivity and specificity. The comparison between each adjunct prediction is illustrated in Figure 4.

Based on the data, the prediction of routine adjunct was highly accurate, with 48 out of 49 cases being correctly predicted. Only one case required the use of another adjunct for treatment completion. Of the 57 cases without a routine adjunct prediction, 54 were accurately predicted. Three cases had their dental treatments completed without any sedation or GA, meaning that their original predictions were inaccurate. The selection of routine care demonstrated excellent accuracy (96%), precision (98%), sensitivity (0.94), and specificity (0.98).

There were only five cases with a prediction of inhalation sedation. All of them showed a perfect prediction with no false positive. Therefore, the selection of inhalation sedation had accuracy and precision rates of 100%, with sensitivity and specificity of 1.00.

Regarding IV sedation, the prediction of 22 in 29 cases was accurate. Seven cases required other adjuncts for their completion of treatment. When IV sedation was not selected, it was a perfect decision as all of them (77 cases) did not need IV sedation for treatment. When predicting IV sedation, the accuracy rate was 93%, while the precision rate was only 76%. Lastly, the selection of IV sedation got a sensitivity of 1.00 and a specificity of 0.92.

For GA, there was one case in which GA was not initially selected, but it ultimately needed GA for the treatment. GA was accurately selected for 22 out of 23 cases. On the other hand, there were six cases of actual GA use without their original GA plans. The amendment lowered its sensitivity to 0.79, while its specificity remained excellent (0.99). The selection of GA displayed very high accuracy and precision rates, which were 93% and 96%, respectively.

In summary, overall accuracy, precision, sensitivity, and specificity can be compared and displayed in Figure 4. Accuracy across adjuncts was excellent, ranging from 93% to 100%. Precision was excellent for routine, inhalation sedation, and GA predictions, ranging from 96% to 100%, whereas precision when predicting IV sedation was 76%. The reason for this is largely because IV sedation was frequently predicted at the first instance, rather than GA, in those cases whose cooperation may be difficult. Sensitivity was at a maximal value when inhalation sedation and IV sedation were predicted. This is because there was no false negative value when predicting none of these but requiring them for the treatment. A small false negative value when selective routine modality led to its sensitivity of 0.94. In contrast, sensitivity was only 0.79 when predicting GA because six cases did not have an original plan for GA, but they required GA for the treatment. Overall specificity was at a good level (0.92 – 1.00) with some false positive values for routine setting, IV sedation, and GA.

Table 16: Confusion matrix for adjunct 1 (Routine)

Act-TA / Pre-TA	Routine	Sedation/GA
Routine	**48**	**1**
Sedation/GA	**3**	**54**

Table 17: Confusion matrix for adjunct 2 (inhalation sedation)

Act-TA / Pre-TA	N_2O	Non-N_2O
N_2O	**5**	**0**
Non-N_2O	**0**	**101**

Table 18: Confusion matrix for adjunct 3 (Intravenous sedation)

Act-TA / Pre-TA	IV	Non-IV
IV	**22**	**7**
Non-IV	**0**	**77**

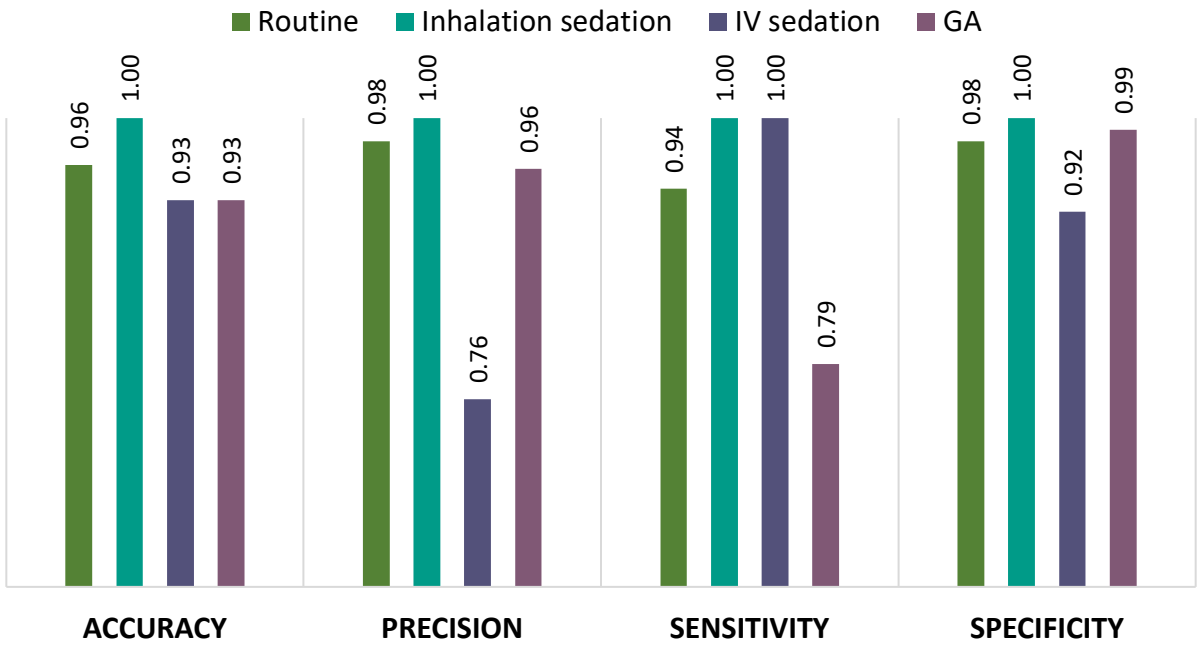
Table 19: Confusion matrix for adjunct 4 (General anaesthesia)

Act-TA / Pre-TA	GA	Non-GA
GA	**22**	**1**
Non-GA	**6**	**77**

Table 20: Accuracy, precision, sensitivity, and specificity for each adjunct

Pre-TA	**Accuracy** (%)	**Precision** (%)	**Sensitivity** (max=1)	**Specificity** (max=1)
Routine	**96%**	**98%**	**0.94**	**0.98**
Inhalation	**100%**	**100%**	**1.00**	**1.00**
IV	**93%**	**76%**	**1.00**	**0.92**
GA	**93%**	**96%**	**0.79**	**0.99**

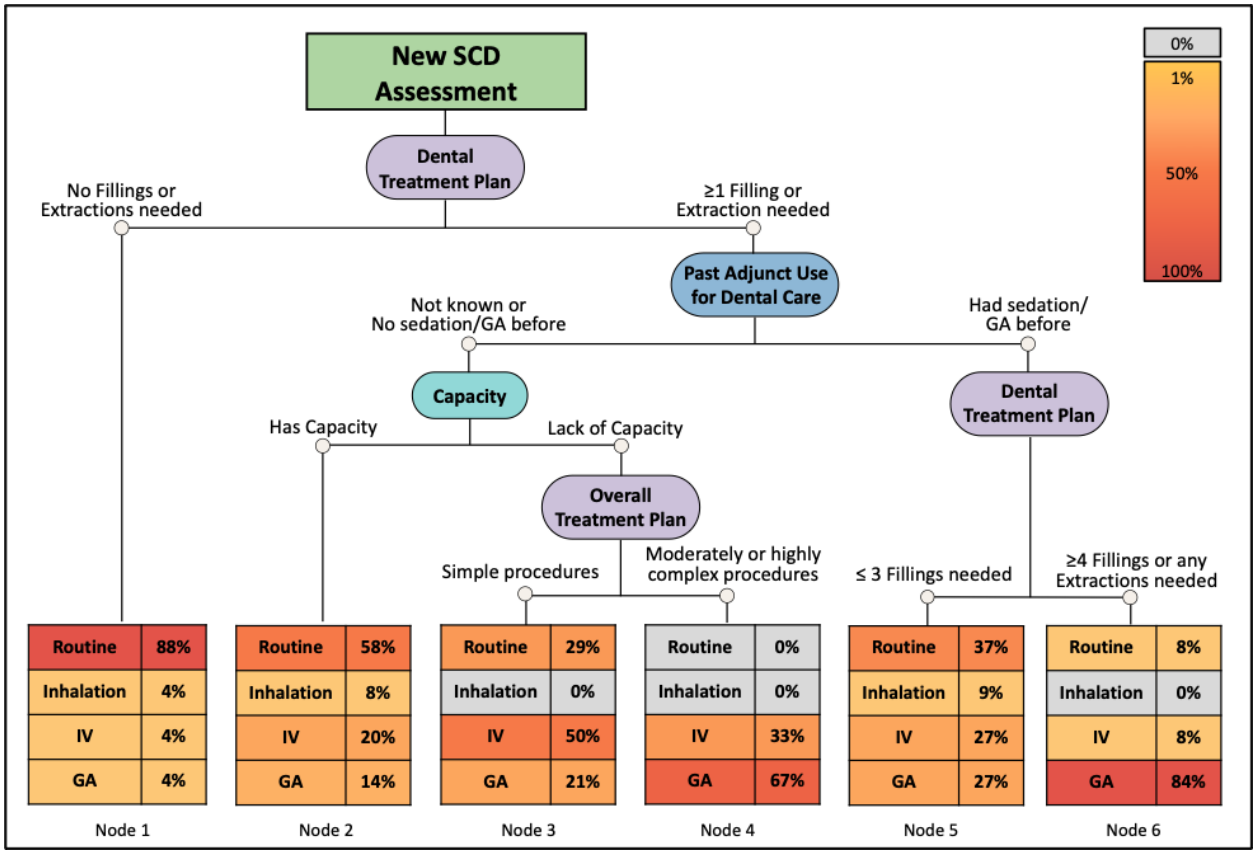
Figure 4: Accuracy, sensitivity, specificity, and precision rate in a bar chart



5.6 A prediction model for Predicting Successful Adjunct Use

An online platform (Posit Cloud) was used to analyse and generate a prediction model statistically. A number of variables were fed into the programme in order to find a suitable model with clinical relevance. Among a number of generated models, this prediction model (Figure 5) showed a promising result to be a proposed model to support future treatment adjunct selection. An example of unqualified models will be explored in *Appendix H*.

Figure 5: A proposed prediction model to assist future treatment adjunct selection



According to Figure 5, the model shows decision-making steps to assist in the selection of successful treatment adjuncts to be used. There were six terminal nodes representing probabilities of using each adjunct as a successful modality. Probabilities were shown in a heat map appearance, ranging from red (100%) to yellow (1%), while grey represented 0% or no data in this study. In this model, there were one to four steps requiring decisions to be made

to go further. Five decision nodes from three main factors were presented in this prediction model. These three factors to be considered when making decisions are:

1. Past adjunct use for dental care
2. Capacity evaluation
3. Dental treatment plan

From the top, when there is a new assessment in SCD, the first factor to be considered is a dental treatment plan, whether there is any filling or extraction required. If there is no filling and extraction required, the probability of using a non-pharmacological adjunct as an actual adjunct is 88%, followed by inhalation sedation, IV sedation, and GA, with a 4% chance each (Node 1).

Node 5 and Node 6 are those who have filling and/or extraction planned and have previous history of using sedation or GA for dental treatment. The new cut-point at three fillings then needs to be considered. Node 5 should be looked at If the patient requires no extraction and three or fewer restorations, while Node 6 is when there are four or more restorations required or any extraction needed in the treatment plan. At Node 5, the probability of using routine modality is the highest among others at 37%, followed by IV sedation and GA (27% each). Only a 9% chance of using inhalation sedation is shown at this node. At Node 6, the biggest probability goes to GA (84%), followed by routine and IV sedation (8% each).

When the patient has no history of using sedation or GA for dental treatment in the past, capacity evaluation plays a critical role in dividing Node 2 and the others. Node 2 is considered when the patient has capacity to consent, which shows the highest chance of using routine as a successful modality (58%), followed by IV sedation (20%), GA (14%), and inhalation sedation (8%). In contrast, if the patient is evaluated as lack of capacity, the complexity of the overall dental treatment plan should be then considered. In this study, units of dental activity (see section 4.4.1 J. details of dental treatment plan) was used to classify the complexity of the dental treatment plan into low (≤10), moderate (11-25), and severe (≥26). If the dental treatment plan falls into a category of low complexity, IV sedation shows the most excellent chance of being a successful adjunct (50%), followed by routine (29%) and GA (21%) (Node 3).

However, GA has the highest probability (67%) when the dental treatment plan has moderate or high complexity. IV sedation comes in a second place with a 33% probability. According to this study, routine and inhalation sedation do not become successful adjuncts for this group of patients (Node 4).

Regarding the ROC curve and its AUC, the *'one-vs-rest approach'* was applied because of multiple dependent variables. Figures 6-9 show plots of ROC and their AUC for each treatment modality when compared to all other modalities, with class 1 representing routine, class 2 representing inhalation sedation, class 3 representing IV sedation, and class 4 representing GA. The AUC for each treatment modality were 0.96, 1.00, 0.96, and 0.89 for routine, inhalation sedation, IV sedation, and GA, respectively. The proposed model was best to differentiate those who need inhalation and who do not. Similarly, it had a 96% performance in a group of routine and IV sedation, while having only 89% performance in the GA group. Overall, our prediction model could be a meaningful supporting tool with good-to-excellent discriminative abilities (Muller et al., 2005). A larger sample of patients, however, is required to be able to test the model using a training-testing split of data more effectively (Poldrack et al., 2020).

Figure 6: The ROC curve for non-pharmacological behavioural support

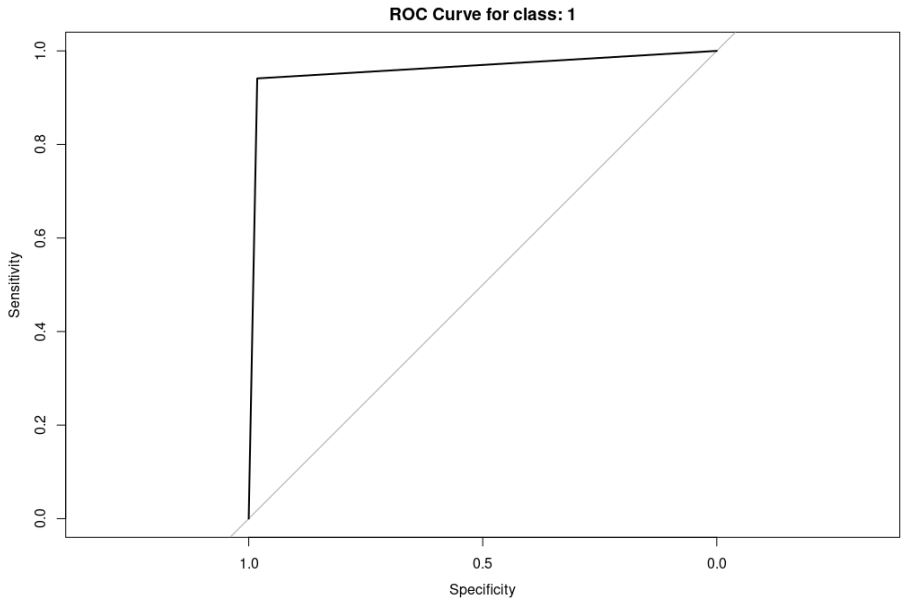


Figure 7: The ROC curve for inhalation sedation

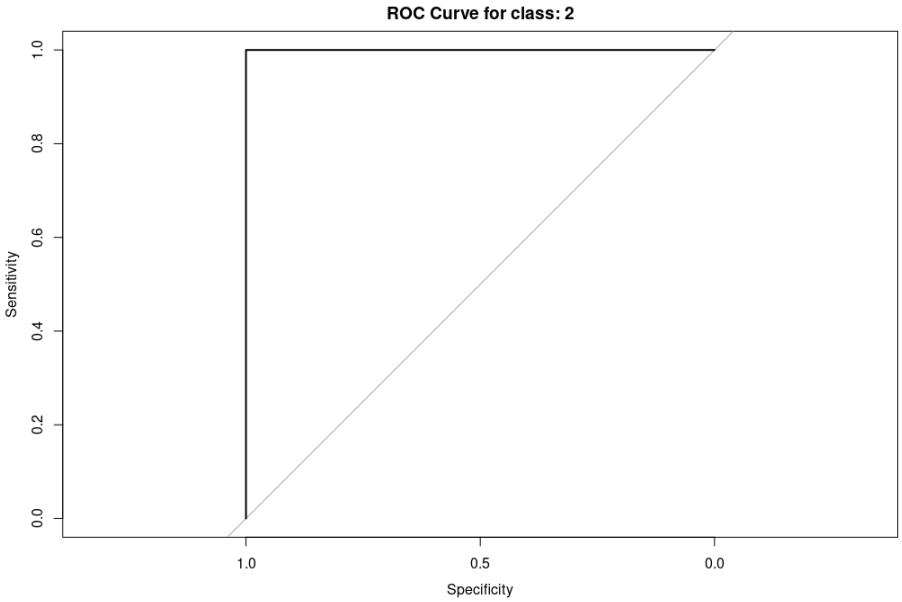


Figure 8: The ROC curve for IV sedation

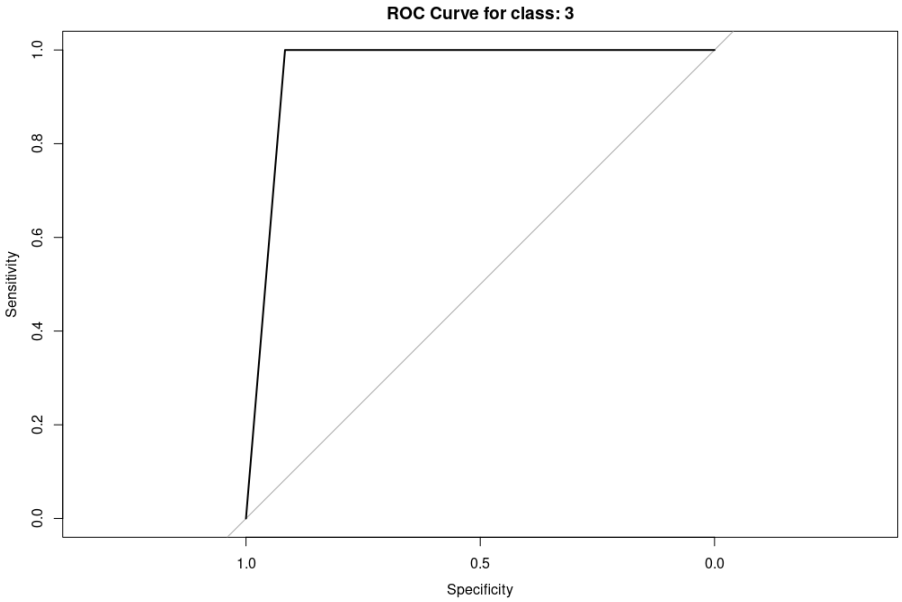
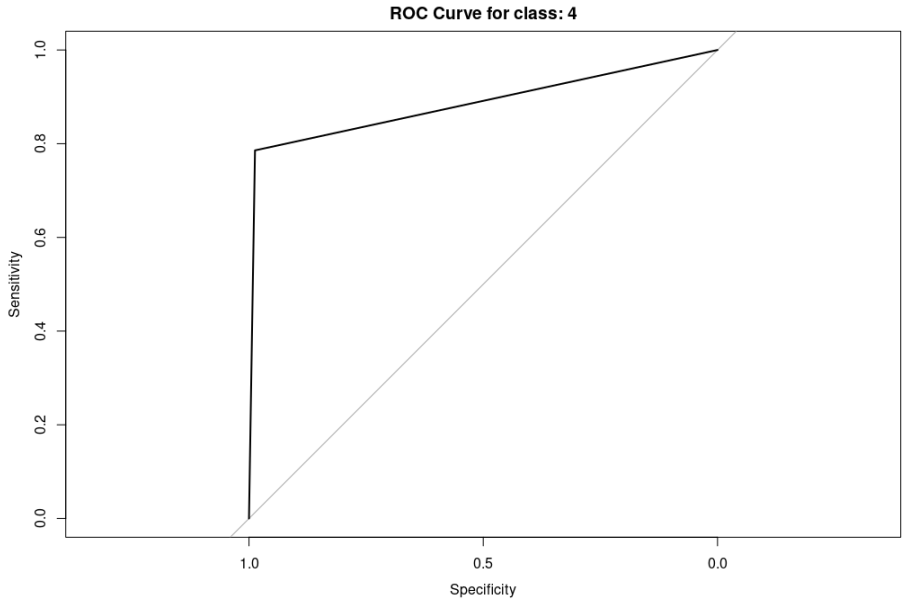


Figure 9: The ROC curve for GA



5.7 Other Findings

According to 103 referral letters, 29 cases (28.16%) were requested or suggested the use of sedation or GA for their patients. As displayed in Table 21, seven of these cases (24.14%) were successfully treated without any form of sedation or GA. The others (n=22 cases, 75.86%) were successfully treated with GA, IV sedation, and inhalation sedation for ten cases (34.48%), eleven cases (37.93%), and one case (3.45%), respectively. It showed a precision rate of 75.86%, an accuracy rate of 63.11%, a sensitivity of 0.42, and a specificity of 0.86.

Table 21: Confusion matrix when sedation or GA was requested in the referral letter and their actual treatment adjuncts

Act-TA / Letter	Sedation/GA	Routine
Sedation/GA requested	**22**	**7**
Non-specific	**31**	**43**

6. Discussion

At the outset, the primary objective of this study was to evaluate the accuracy of past clinical decision-making in the prediction of treatment modalities for patients requiring Special Care Dentistry (SCD) and, subsequently, to propose a supporting tool for future clinical decision-making. This study found near perfect overall accuracy rate of the performance during 2020-2021. Two significant factors which predicted accuracy were the presence of challenging behaviour and the urgency of treatment. The second set of analyses explored the successful use of individual treatment adjuncts. The data fitted a prediction model that possessed three major influencing factors, which were dental treatment plan, past adjunct use for dental care, and patient's capacity to consent. These findings are considered in turn, with references or relevant literature below.

6.1 Overall Accuracy of Treatment Adjunct Prediction

The first question this study aimed to answer was how accurate are the clinicians in predicting treatment adjuncts for patients requiring SCD. The results indicated that accuracy of predicting the right treatment adjunct for successful treatment outcomes in this study was 91.51%. Since there is no literature in grading the predictive accuracy to rely on, the interpretations from other relevant fields were adapted, which a 91.51% in their studies could be interpreted as 'almost perfect' (Landis & Koch, 1977), 'excellent' (Muller et al., 2005), or 'reassuring high' (Sanjay et al., 2012). Therefore, we could summarise that our accuracy rate was at excellent level. On the other hand, it briefly showed that the wrong predictions occurred in almost one every ten cases. Three main reasons for the inaccurate predictions were sedation failure, service availability, and medical complexity. The majority of failure was detected when predicting the use of IV sedation. Difficult venipuncture was one of the reasons for a change in treatment modality. It could be an anatomical or behavioural problem. It sometimes failed because the patients did not drink the oral pre-medication, which then led to under-sedation and difficulty in cannulation due to cooperation. In contrast, over-sedation could be another reason for the selection failure, which required the termination of the procedures by administering a reversal medication and modifying the plan. Additionally, modifications of

treatment adjuncts were due to the availability of the service. The increased urgency of the treatment, such as having pain or swelling, required a sooner appointment.

These findings can be understood by considering typical clinical instances that are considered urgent. The presence of symptoms makes the treatment urgent, which impacts the selection of treatment modality to be based on availability or short turnaround to treatment, rather than on its optimal probability for success. Limited cooperation may be a barrier to performing complete examinations and additional tests, as well as proper treatment or management. IV sedation was often picked for these patients because routine and inhalation sedation require a certain degree of cooperation. At the same time, GA should not be used as the first-choice approach without known or suspected conditions (Geddis-Regan et al., 2022). In addition, GA is relatively inaccessible with much longer waiting times. In those cases, with incorrect predictions, the original modalities were replaced by GA as it could ensure a quality of pain assessment at an earlier date. High dental treatment needs were another cause of the treatment adjunct modifications. Despite a long waiting list, all required dental procedures could be accomplished quicker under GA rather than a few visits of IV sedation. Lastly, the predicted treatment adjunct was deemed inaccurate due to medical reasons after an anaesthetic consultation.

6.2 Implications of the Accuracy Rate of Treatment Adjunct Selection

A perfect score of accuracy in treatment adjunct prediction was never expected due to the concept of minimal intervention dentistry and avoidance of over-treatment, such as GA. Following the non-invasive approaches by employing a range of non-pharmacological behavioural support techniques cannot only avoid the need for sedation or GA but also allow patients to learn how to cope with dental treatment and develop better relationships with dentistry (Lyons, 2009).

On the contrary, in order to be more accurate in the future, providers should pay more attention to pre-sedation assessment, urgent care pathway, and medical assessment. Pre-sedation assessment should follow the existing guidelines from the IACSD and SDCEP, for

example (Intercollegiate Advisory Committee for Sedation in Dentistry, 2020; Scottish Dental Clinical Effectiveness Programme, 2017), particularly a prudent titration of midazolam to the patient's response. One of the keys to being efficient in IV sedation is higher success rates of cannulation at the first or second attempt (Wilson et al., 2011). In our practice, a glass of carbonated drink containing midazolam was sometimes given to the patients pre-operatively for anxiolysis and to facilitate safe cannulation. Oral route is typically the least restrictive approach (Geddis-Regan et al., 2022), but it could be unsuccessful if the patients were lack of compliance to drink the oral preparation. Transmucosal administration via buccal and intranasal routes could be a promising option to solve this issue. Still, both techniques are recognised as the basic sedation techniques (Scottish Dental Clinical Effectiveness Programme, 2017). Intranasal sedation may show a slightly better performance in this situation because the buccal administration still requires certain levels of compliance to open the mouth and not spit the medication due to the bitter taste of midazolam (Sunbul et al., 2014). Intranasal sedation, once sprayed, has the advantages of direct drug absorption to the systemic circulation and minimal requirement of patients' cooperation (Ashley et al., 2021). The patients may exhibit resistance because of the irritation and discomfort associated with the method of administration (Sunbul et al., 2014). Furthermore, an audit of sedation in adults with disabilities revealed that intranasal sedation with midazolam could support the effectiveness of cannulation at 96.2% (Ransford et al., 2010). It also showed 91.45% of successful episodes of IV sedation in patients with disabilities who had been referred for GA following failed treatment sessions with behavioural support, inhalation sedation, and cannulation (Manley et al., 2008). Lastly, it is necessary to support education and training in providing conscious sedation for people requiring SCD, especially the skill to insert a cannula (Wilson et al., 2011; Mac Giolla Phadraig et al., 2018).

In terms of service, it is best to have an urgent care pathway or a contingency plan prepared for patients who have increased dental treatment needs, such as having pain or symptomatic problems. Many studies advised dentists to accept uncertainty in dental procedures and learn that having to repeat the treatment is not a failure (Mac Giolla Phadraig et al., 2022b; von Bergmann & Shuler, 2019). Lastly, underlying medical issues can limit the use of some

treatment modalities, which the dentists must be able to identify and communicate with the medical and anaesthetic team for multidisciplinary planning. In our study, GA was not proceeded in one case due to severely high BMI. Patients with elevated BMI are at higher risk of having complications during GA, specifically related to the respiratory function, such as difficult airway management, difficult intubation, and the risk of developing postoperative pulmonary complications (Bazurro et al., 2018). Therefore, it was a safer choice to alter the treatment adjunct to suit the patient's medical status. Many factors can limit the ability of anaesthetic assessment, including lacking medical workups, suboptimal airway assessment due to uncooperative behaviour, lack of supportive system for both preoperative and postoperative cares, and lack of pre-surgical workups to understand the extent and length of treatment (Messieha, 2009). The last situation could be a common problem in dentistry since a thorough oral examination prior to the GA visit may not be achieved in most cases requiring GA.

The present study had an almost similar accuracy rate to another study, which used teledentistry for treatment planning in a paediatric dentistry clinic. The authors found an 86.5% accuracy rate, and they discussed that obtaining new information was the main reason for the inaccurate predictions. New information included radiographic examination and behavioural evaluation, as behaviour had been more challenging during more invasive treatment (McLaren et al., 2017). Similar to our study, their study was designed as a retrospective chart review to assess the accuracy of predicting treatment modalities. However, they evaluated the performance of using a live-video teledentistry rather than our study's on-site clinical examination.

Interestingly, our result revealed that the predictions were always accurate in patients without neurodisability, either neurodevelopmental disorders or acquired neurological disorders. Future studies may benefit from focusing on patients with neurodisability only in order for better time management and reasonable resource utilisation.

In conclusion, there are a few key points that we can learn from past performances. The failed prediction rate can be lessened by better comprehensive planning prior to IV sedation and

thorough medical assessment and consultation. Moreover, having a backup plan in place can support the administrative management in case of increased treatment needs or urgency.

6.3 Predictive Variables for Overall Accuracy of Treatment Adjunct Selection

From almost 40 variables, there were only two variables that significantly influenced the accuracy of treatment adjunct selection, which were the presence of challenging behaviour (OR = 0.10; 95%CI = 0.02 - 0.66) and urgency (OR = 0.06; 95%CI = 0.01 – 0.72). Both of them showed a negative relationship to the decision-making performance. It can be interpreted that when there is an urgent need for dental treatment, the odds of making an accurate prediction are only 6% as compared to the situation without an urgent need, or it is 16 times less likely to be accurate if the patient has increased the urgency of treatment. While the patient presented with challenging behaviour, the accuracy rate of prediction is only 10% as likely to occur in the patients without challenging behaviour, or it is ten times less likely to be accurate. Moreover, the presence of neurodevelopmental disorder could be a potential factor, but not significant, to the accuracy of treatment modalities selection (OR = 0.15; 95%CI = 0.01 – 0.80). It should be noted that the limitation of the retrospective design is the lack of some potential variables that may probably impact the accuracy of treatment adjunct selection. According to Varela et al. (2021), some potential factors included the behaviours during shaving and toothbrushing, noise and vibration intolerances, and the behaviours in other diagnostic tests, such as when undergoing a blood test, extraoral radiography, and an electrocardiogram (Varela et al., 2021). Further potential variables may include:

- The number of carers present at the appointment.
- Distance from the patient's address to the hospital.
- Experiences of assessors in the field of SCD, such as first year and last year postgraduate trainees.
- Statistical backgrounds in treatment adjunct selections and attitudes of assessors
- Clinical supervisor on the assessment visit
- Days or sessions of the assessment visit
- How long the waiting lists were, at the assessment visit

Challenging behaviour, in this study, was defined as the behaviours that limit the exercise of dental activities in a dental service, including clinical examination, radiographic examination, and treatment. The definition was adapted from the study about clinical holding in SCD, which assumes the indication of clinical holding to be employed in cases with challenging behaviour. It explained the situation where clinical holding is required as *'when there is the behaviour that limits the ability of the dental team to effectively deliver the treatment or where the behaviour may present a safety risk to themselves, members of the dental team, or other accompanying persons'* (Kerr et al., 2013). Based on the retrospective design, it might not be absolutely clear how to obtain information on challenging behaviour. It was checked as the patients had challenging behaviours if the treatment records showed any keywords of 'having challenging behaviour', 'having behaviour of concerns', 'requiring clinical holding', or 'requiring behavioural risk assessment and management plan'. The method to collect the behaviour information may have high sensitivity but low specificity, which might lead to a certain degree of unreliability in this study. A clear line may need to be drawn in the future studies to distinguish the patients who exhibited challenging behaviour from those who did not. For this reason, a tool to assess the degree of cooperation should be implemented in order to validate the treatment record, use as a screening tool, and support further decision-making in case of challenging behaviour. One of the existing tools is the original Venham scales which comes in formats covering anxiety and uncooperative behaviour (Venham et al., 1980). It consisted of both anxiety rating scale and behaviour rating scale, which was originally designed for paediatric patients. The adaptation of the scales could be a potential resource to identify and quantify the behaviours that challenge or limit dental care in adults with disabilities. The scales may be integrated into the SCD assessment process, or once required, in order for future studies. Its modified version has been used as a cooperation component in the French Case Mix Tool (Faulks et al., 2023). Alternatively, the implementation of any form of behavioural risk assessment and management plan should identify the person with challenging behaviour in dental setting. At DDUH, the local document of *'Behavioural Risk Assessment and Management Plan'* can imply the presence of challenging behaviour.

The prevalence of having challenging behaviour was about 10 – 15% in people with intellectual disability, and it tended to be persistent and stable across their lives (Totsika & Hastings, 2009). A study in Wales included four types of challenging behaviour, including aggression, self-injury, destructive behaviour, and difficult/disruptive behaviour. They found that 10% of people with learning disability were rated as having serious challenging behaviour, with non-compliance being the most prevalent characteristic (Lowe et al., 2007). Challenging behaviour has multiple functions, including escape, attention, non-social, tangible, and problem behaviour related to pain. Escape was the most common function to be identified when the behaviour had only one function, but multiple functions were found to be shared (Benson & Brooks, 2008). It could be a result of the inability to communicate pain or discomfort in patients with poor expressive communication (Manley et al., 2000).

Challenging behaviour is a significant problem for individuals with intellectual disability (Benson & Brooks, 2008) and has been a serious issue in dentistry as it can limit clinical cooperation, reduce self-care, frighten the caregivers as well as the dental professionals, and the later stage, require specialist care centre or sedation/GA for treatment (Manley et al., 2000). All of these reasons can increase rates of dental avoidance, which lead to high levels of untreated dental diseases and poorer oral hygiene in those patients with challenging behaviours due to acquired neurological disorders (Robbins, 2016) or neurodevelopmental disorders (Sami et al., 2023). Treatment planning for patients who exhibit challenging behaviour can be very challenging. There are several points of concern that the chosen treatment modality may not be successful. For example, they may not be able to tolerate routine examination and treatment without the use of sedation or GA, accept the mask during inhalation sedation, or allow a safe cannulation process for IV sedation. However, conscious sedation was encouraged to be used as an alternative to GA with an adapted and flexible approach (Manley et al., 2000). In other studies, the presence of challenging behaviour was considerably associated with an inability to cooperate with an oral health screening (Du et al., 2015) and was one of the predictive factors of the use of conscious sedation or GA (Mac Giolla Phadraig et al., 2018). Another study presented a likelihood of having dental treatment under GA in children with problems in interpersonal interactions and relationships (Norderyd et al.,

2018). Together with its difficulty in treatment planning and predictability, challenging behaviour was also cited as the most frequent barrier to care (Smith et al., 2010).

It could be concluded that patients with challenging behaviour can be neglected, which could worsen their dental status and lead to more severe oral problems. Our study suggests the importance of adapted care for people with challenging behaviours, including the improvement of access to dental care under any treatment modalities and the development of training in dental behavioural support techniques, both non-pharmacologically and pharmacologically.

Another influencing factor was the urgency of treatment. Urgency in our study was checked when the referring person mentioned pain, infection, swelling, or any conditions that implied the urgent need for assessment or treatment. However, due to the nature of SCD service at the DDUH, many practitioners wanted to refer their patients to be accepted for care. They often quoted 'pain', 'infection', or other symptomatic conditions in the letters where the patients actually might not be qualified for the treatment in the specialist service. Therefore, the urgency might not be precise, but it did show a powerful negative correlation with the accuracy of treatment adjunct selection. In terms of practice, they were often put into IV sedation to reassess the issue while avoiding the use of GA. This urgent situation could be the leading cause of inaccuracy when predicting the use of primary adjuncts. The wrong prediction may be caused by unsuccessful sedation, new information gathered, or the need to change the dental procedure. Another article showed that obtaining new information could lead to the change of original treatment planning. Two outstanding examples in their study were new information from radiographic examination and behavioural assessment (McLaren et al., 2017).

Ideally, a treatment plan for people with anxiety or disability should be sequenced from the simplest and non-invasive treatment to the most difficult and complex procedure. However, in terms of ethics, it may not be possible in those cases requiring urgent interventions because the procedures to deal with urgent problems are usually invasive and complicated, such as extraction, root canal treatment, or deep root debridement. The situation becomes more

complex in patients with limited expressive communication or non-verbal communication. Assessing pain without the ability to self-report demands a supporting tool, but no such tool has high-quality evidence to support its reliability, validity, and clinical utility (Lichtner et al., 2014). Consequently, treatment modality is hard to choose correctly at the beginning, and it may require modification to support the completion (Heidari et al., 2020). Therefore, urgency can impact the decision-making in SCD as it was brought up as an additional factor to be considered when selecting the treatment modality (Glassman et al., 2009). It was advised that urgent care may benefit from pharmacological modalities, together with non-pharmacological behavioural support techniques (Heidari et al., 2020).

The urgency of treatment can lead to uncertainty, which is a crucial problem in medicine and dentistry. Uncertainty tolerance is associated with several outcomes in healthcare and healthcare education (Strout et al., 2018). Recognising the potential for uncertainty is also a necessary skill that healthcare professionals should be comfortable with, as well as how to manage an uncertain situation (von Bergmann & Shuler, 2019). A study showed that medical students with a lower tolerance of uncertainty significantly had higher psychological stress (Lally & Cantillon, 2014). Because urgency is an unavoidably uncertain problem in dentistry, especially in SCD, it is highly suggested that the dentists who work in the field of SCD should train on uncertainty tolerance skills and have a plan in place for the patients who require the modification of treatment modalities for their urgent problems.

To summarise the outcome of this study relating to overall accuracy, while the prediction rate was very accurate, the predictions tend to be far less accurate in patients who exhibit challenging behaviour or have urgent dental issues. Nevertheless, these findings do not suggest the use of GA in all such cases, but a contingency plan should be in place to support those cases where the less restrictive option was not effective. The continuation of treatment, in these cases, should be prioritised in order to decrease waiting time from being moved to another waiting list. Moreover, all people with disabilities, including those patients with challenging behaviour and urgency of treatment, have the right to equal services and treatments, including minimal restrictions and minimal interventions (United Nations, 2006).

Decisions on the treatment plan must incorporate the values and preferences of these patients (Legare & Witteman, 2013). Concurrently, dentists must learn to accept the uncertainty of treatment and the failure of the chosen modality, if unsuccessful, in order to reduce over-prescription of invasive modalities, such as GA (McGeown et al., 2022; Mac Giolla Phadraig et al., 2022b).

6.4 Accuracy Across Each Treatment Adjunct

When focusing on details across each treatment adjunct, the results showed excellent accuracy rates for all adjuncts, ranging from 93% to 100%. It must be noted that there was only a small number of cases in the inhalation sedation group (n=5). Precision rates were excellent, ranging from 96% to 100%, for routine, inhalation sedation, and GA. However, IV sedation had a relatively low precision rate of 76% because it was often used as a method for patients who may not be cooperative for treatment but attempt to avoid GA. Our past performance had favourable sensitivity and specificity across all adjuncts, except sensitivity when predicting GA. A comparatively low sensitivity was because a number of cases used GA as their actual adjunct to provide care, whilst GA was not their original prediction. Overall, the results revealed favourable outcomes with a need to improve the precision rate when predicting IV sedation.

In other studies, GA was the most successful adjunct use in paediatric patients who were referred to a specialist centre due to lack of cooperation, while inhalation sedation with nitrous oxide had six times more failure rate than using GA (Blumer et al., 2019). Similarly, a retrospective chart review in prediction using teledentistry revealed that 32.26% of the children in the inhalation sedation group had their treatment modality changed, while there was no change when predicting GA (McLaren et al., 2017). Predicting inhalation sedation in paediatric patients may share the same rationale with predicting IV sedation in the adult population in our study. Sedation techniques could be used to treat patients with suspected cooperation issues, while trying to avoid the use of GA. On the other hand, a multicentre study in France displayed a high success rate of 91.4% when using inhalation sedation with nitrous oxide in the patients who were referred to the hospitals due to cooperation issues (Faulks et

al., 2007). Lastly, a study in Scotland revealed that the success rate when using inhalation sedation with nitrous oxide in paediatric patients was 93% (Foley, 2005).

In our study, IV sedation with midazolam was correctly predicted in 76%. It must be noted that this study used only single-drug IV sedation with midazolam. It does not include anaesthetist-led IV sedation, different sedative agents, a combination of drugs, or other complex techniques. The use of preoperative oral sedation prior to cannulation and IV sedation is considered an 'advanced sedation technique' due to the combined routes of administration (Scottish Dental Clinical Effectiveness Programme, 2017). It can promote better accuracy in performing IV sedation by facilitating successful cannulation because this was one of the reasons of wrong prediction. On the other hand, oral sedation was another direct cause of failure when the patient did not consume an oral preparation of midazolam. Therefore, it was inconclusive in this study whether preoperative oral sedation should be routinely implemented in IV sedation cases. Furthermore, the use of an infrared vein-finding technology may be helpful in vein visualisation and support successful cannulation (Chiao et al., 2013).

A retrospective audit of 124 patients who were planned for sedation with midazolam, in contrast, presented a 96.77% accuracy rate with failure in only four cases, which subsequently required GA (Manley et al., 2000). In a classic study using a combination of IV drugs, predicting IV sedation was accurate in 95.83%, while four cases received their dental care under GA after that (Malamed et al., 1989). Another study using a combination of intranasal and intravenous sedation with midazolam had a 91.44% accuracy rate of prediction, in which 63.05% of them had excellent sedation scores, and 36.95% of them had little difficulties but did not compromise the treatment. The dental procedure was not possible in 8.55% of cases where referrals were made for GA (Manley et al., 2008). The differences among these studies may be due to patient selections, techniques, and factors related to dental professionals. To date, most studies in treatment modality prediction were performed in a paediatric population. There is a strong need to develop a better understanding of the group of adults with disabilities.

6.5 A Proposed Prediction Model

A proposed prediction model was generated by machine learning software, using the classification tree method. The proposed model was the most useful version, among others, with potency for clinical implications. According to the guide to presenting clinical prediction models, our model was a prognostic prediction model presented using a graphical score chart in the format of a decision tree flow chart (Bonnett et al., 2019). Three factors were included according to their statistical significance: dental treatment plan, past dental history, and mental capacity. The model was intended to be made effortless to understand and simple to use by having only three factors to be considered, six different endpoints, and a maximum of four dichotomous decisive steps. At the endpoints, the model did not decide the best treatment modality of each pathway, leaving the probabilities of each adjunct to be agreed at the operator's discretion and available healthcare resources (Varela et al., 2021). Therefore, a final decision can be made on a case-by-case basis, given the diversity of the patients requiring SCD and the differences among centres. Lastly, a shared decision-making process is essentially encouraged by involving the patients themselves in the care pathway (Legare & Witteman, 2013; Geddis-Regan et al., 2024c). This is an important point for the patient's perspective that should not be omitted (Geddis-Regan et al., 2024a). The concept of shared decision-making model can play an essential role at this point by integrating the probabilities from the proposed model with the patient's preference in order to reach the agreed treatment plan (Charles et al., 1997). However, it may sometimes be challenging in patients requiring SCD, especially those who are unable to give consent themselves. Therefore, the shared decision-making may be optimised by involving patients' caregivers or employing the best interest approach, in which the preferences of the dentists could play a more active role in leading the decision-making processes.

One of the limitations of this model is that there were some options with no chance (0%) to be successful adjuncts in some pathways, such as inhalation sedation in Node 3, 4, and 6 and routine in Node 4. These values do not reflect real clinical situations, and it is agreeable that the model requires more inputs to eliminate these blank values. According to Riley et al. (2024), many studies in clinical prediction models needed to be bigger to provide reliable

answers, and they often had wide confidence intervals and potentially misleading implications (Riley et al., 2024). It was strongly advised that a larger sample size is required to precisely estimate the predictive performance. Their suggestions can also be applied to our study, which needs a bigger sample size for validation and generalisation of the results. Fresh data is needed to test the model and avoid the overfitting.

Another limitation of the model is the clarification of dental treatment plan. Sometimes, it may not be possible to have a definite dental treatment plan from an assessment visit because of a few reasons, including cooperation issues, the need for further investigations, increased severity of dental diseases, symptomatic problems, treatment philosophy of different assessors, and patient preferences. Two cut-points were shown in the model by their statistical significance, including having a plan of extraction or not and having between three or fewer and four or more fillings. Complexity of dental treatment plan, in this study, used the Units of Dental Activity as a quantitative tool (National Health Service England, 2023; (no author listed), 2016). It was classified into three groups according to the UDAs, which were low/simple complexity (0-10), moderate (11-25), and high (26 or more). To sum up the UDAs score, a complete plan describing all dental treatment needs is required, which may not be practicable. In this situation, the operators need to use their heuristic approaches to classify the overall plan, whether it is simple, moderately complex, or highly complex. Moreover, the UDAs do not include all aspects of dental procedures, particularly complex surgical procedures, such as endodontic surgery, periodontal surgery, biopsy, and dental implants. When following the proposed prediction model, only extraction and restoration are mainly considered. All types of surgeries may be regarded as extraction, while root canal treatment may be counted as multiple fillings. The adaptation of the scores requires further criteria to properly quantify the complexity of dental treatment used in this model.

Three key predictors being used for the successful treatment modality were dental treatment plan, past adjunct use for dental care, and capacity evaluation. According to a survey in older adults, predictors for the use of sedation or GA included impaired expressive communication, challenging behaviour, and treatment needs (Mac Giolla Phadraig et al., 2018). The PREBED

model used noise and vibration intolerance, behaviours in daily life activities, and behaviours in other medical diagnostic tests as predictors for conducting GA for dental treatment (Varela et al., 2021). In a study of patients with dental anxiety, the MDAS score, which indicated the level of dental anxiety, and the need for urgent treatment were used to suggest possible approaches to manage dental care (Newton et al., 2012). The SCAN-score had three main items and three additional items to predict the need for GA in children with limited cooperation (Berat et al., 2024). Lastly, the IOSN indicated the need for sedation by using three predictors, including the level of dental anxiety or MDAS score, medical and behavioural indicator score, and treatment complexity score (Coulthard, 2013). The level of dental anxiety seems to be present in a number of predictive tools. However, due to a number of missing data, the level of dental anxiety was not included in the model. The result of this study may inform the practitioners working in the DDUH to ensure gathering information on this topic. Lastly, past adjunct use for dental care was not specific to adulthood only. It was unable to distinguish whether it was used in paediatric services, which may have a smaller impact than it has in the prediction model.

Machine learning models become more popular in healthcare and dentistry in recent years. One of the example models is used for orthodontic diagnosis and treatment planning (Prasad et al., 2022). Another example used machine learning to develop an algorithm to predict untreated dental caries. The developed model showed four crucial variables, including the use of dental floss, unhealthy food consumption, self-declared race, and exposure to fluoridated water (Bomfim, 2024). Previous statistics and evidence-based data can be integrated to develop a guideline, which can be a useful tool to personal experience and expert opinion. However, errors in medical treatment planning cannot be avoided entirely because of many justifiable reasons, such as cognitive biases, mistakes in data interpretation, and uncertainty (Feller et al., 2020). Given the nature of diversity in the patients requiring SCD, the proposed model leaves the final decision at the discretion of the operator by giving successful probabilities of each adjunct at the end of each node. The model does require further validation processes with a larger sample size, which could improve the model validity and support future decision-making process in an assessment clinic. Furthermore, a collaboration

with other centres, where may have different treatment modalities or techniques available, should be commenced, with a careful manipulation of variables to be included and analysed in the model. Additional trainings were suggested to develop knowledge and skills in decision-making, such as theory and simulations in case scenarios, accepting uncertainty, self-assessment and self-awareness, and shared decision-making and consent training (McGeown et al., 2022).

6.6 Accuracy of Referring Dentists' Predictions

An interesting finding emerged during the analysis, even though this knowledge was not originally considered. According to the referral letters, our study found that 63% were accurate in suggesting the use of sedation or GA, predicted by the referring dentists. Any form of sedation and GA were requested in 28% of all incoming cases. The percentages may over-reflect the numbers because the need for sedation and GA was often used as one of the referral reasons in order to persuade the DDUH to accept the patients into care. Interestingly, 24% of them could be successfully treated without the use of pharmacological sedation or GA. Comparatively, a study in paediatric patients found that 47.5% of referrals were inaccurate in children who were referred for dental treatment under GA. Those cases successfully received the planned treatment in routine care, although some of them required some forms of protective stabilisation techniques by either parents, staff, or restrictive devices. It was also revealed that 80% of patients referred by paediatric dentists were correct suggestions, while only 6.7% of patients referred by general dentists were ultimately treated under GA. The results evidently presented the unnecessary referral of GA (Aminabadi et al., 2016). When compared to 91.5% accuracy rate in the specialist service, there is a big gap between these rates, which indicates the importance of non-pharmacological behavioural support techniques training and education in both undergraduate and continuing education levels. The problem remains similar to what concluded in the article published fifteen years ago, where the majority of dental providers were inadequately trained in behavioural support strategies (Lyons, 2009). Furthermore, although the study took place in a tertiary healthcare setting where complex cases are expected, almost half of all patients (n=51, 48.11%) were

successfully treated without sedation/GA. The percentage immensely underscores the necessity of education and training in SCD, which can support not only the skills of dental professionals but also the accessibility of the patients.

6.7 Comparing Findings to An Audit in 2006 - 2007

An audit undertaken in DDUH covering 2006-2007 allows for comparison of the study's results with practice over time. In this study, the patients who were accepted into the SCD clinic, DDUH, had almost an equal number of males (52.83%) and females (47.17%). The mean age at the assessment visit was 43.7 years old, ranging from 17 to 93 years old. In contrast to an audit in the DDUH, it was pretty similar to the distribution in 2007, in which 54.48% were males and 44.83% were female, but with an age range of two to 84 years old. In contrast, there were more females (53%) than males (47%) in 2006 with an age of five to 86 years old (Kelly & Nunn, 2012)

Most patients, in our study, were classified in a group of neurodevelopmental disability (54.72%), mainly the patients with intellectual disability, autism spectrum disorder, and Down syndrome, followed by those with physical disability and medical complexity at a similar percentage (24.53%). These demographics represented the majority of adult patients with disabilities who attended the clinic. It must be noted the lower number of patients in the medically complex group because the DDUH offers additional services outside the dental hospital particularly for people with medical complexities, including those with bleeding and coagulation disorders (at the National Coagulation Centre, St James's hospital), those with pre-transplantation liver disease (at St Vincent's hospital), and those with pre-radiation therapy for head and neck cancer (at Pre-Radiation Oncology Clinic, the DDUH).

In terms of treatment planning in SCD, the majority of the patients were given 'routine' as their initially planned modality (46.23%), followed by IV sedation (27.36%) and GA (21.70%). Only a small number of cases (4.72%) were planned for inhalation sedation in this cohort. However, routine (48.11%) and GA (26.42%) had slightly greater numbers of cases for their actual use, while the number of IV sedation cases dropped (20.75%). Interestingly, the number

of inhalation sedation cases remained the same (4.72%). These numbers could be internally compared with the data in from 2006 to 2007 (Kelly & Nunn, 2012), as presented in Table 22. The numbers of two conscious sedation modalities, inhalation and IV sedation, are merged for comparative purposes. Although there have been several changes in the services, the shape of treatment adjuncts selection in SCD is quite close to what it was 14 years ago.

Table 22: Comparative data of actual treatment adjuncts used to provide care in 2006-2007 and 2020-2021

	2006-2007 (Kelly & Nunn, 2012)	2020-2021 (The present study)
Routine	52.50%	48.11%
Inhalation sedation	25%	25.47%
IV sedation		
GA	22.50%	26.42%

In the present study, GA was actually used to provide care for 26.42% of all patients. It is close to two former studies estimated that around 20% of people with disabilities required GA for the provision of dental care (Holland & O'Mullane, 1990; Leyman et al., 1999). The need for GA, however, in the tertiary health centre was expected to be up to 60% of people with disabilities (Sigal et al., 1988). Therefore, considering the DDUH as the tertiary healthcare level, the prevalence of GA was much lower, which implies the success of using more conservative approaches. Lastly, a classic study in 1985 reported that approximately 35% of adults with disabilities were not able to tolerate dental care and required either intravenous sedation or GA (Malamed et al., 1989). In comparison, our study had a total of 47.17% of patients treated under IV sedation and GA.

The prevalences were obviously different from a national cross-sectional survey of older adults with intellectual disabilities in Ireland. The study reported that almost three-quarters of patients (72.1%) used non-pharmacological supports only. Whereas pharmacological behavioural supports were experienced in smaller percentages: oral sedation (16%),

inhalation sedation (0.9%), IV sedation (2.4%), and GA (8.6%) (Mac Giolla Phadraig et al., 2018). All pharmacological support techniques were relatively compared to our findings. Two major differences were the study populations and the methods of data collection. Our study included patients of all ages with disabilities and reviewed the treatment record, while the previous research focused on older adults and used the patient's self-reports, which may not reflect reality. For example, the number of sedation and GA cases could have been lower than reality due to the characteristics of dementia or the effects of sedative drugs or GA.

6.8 Considerations regarding the Nature of Study Location

The setting of this study was unique since it was performed in a single centre at the Dublin Dental University Hospital, which jointly operates as a dental school and a tertiary healthcare service. In terms of education, operators in the clinic are primarily postgraduate trainees/students who have been rotating due to academic timetables or changed due to completion of the course and acceptance of new trainees. The skills of operators can differ from one to another and from the level of training, which could be one of the factors that influence the selection of behavioural support techniques (Mac Giolla Phadraig et al., 2022a). Similarly, a study in the Middle East showed a significant difference in accuracy in treatment planning between two groups of dentists with different levels of training (Aminabadi et al., 2016). Apart from the postgraduate students, there was a slight transition in the placement of an SCD specialist who covered the clinical sessions during the time of the project. Lastly, positions of non-consultant hospital dentist/doctor (NCHD) or house officer have changed yearly due to their contracts. Also, a position in an SCD clinic has been changed every few weeks among the NCHDs. Therefore, constant changes in these roles could affect the continuity of the service and clinical decision-making in treatment planning, as well as the patient's trust (Armfield et al., 2017).

In terms of healthcare service, our centre is a specialist-based tertiary care that accepts referrals from other primary or secondary services. In order to be accepted in the clinic, each referral letter requires a careful screening by a responsible specialist. Only those patients with complex disability or urgent needs could be accepted for assessment and treatment at a

standardised discretion. It was estimated that 90% of people with special needs could be treated in the general dental service if the accessibility issue was addressed (Gallagher & Fiske, 2007). Therefore, those with low complexity whose treatment adjuncts may be easier to predict were rejected and returned to be treated by local services.

The unique nature of the SCD service in DDUH could influence how decisions on treatment planning have been made, which then can affect the accuracy of treatment adjunct prediction. The centre of this study offers four treatment modalities, which may be different from what other centres do. Non-pharmacological or routine setting is available in a typical dental unit at the SCD clinic. Two standard conscious sedation techniques are available: (1) inhalation sedation with nitrous oxide and oxygen and (2) intravenous sedation with midazolam (Scottish Dental Clinical Effectiveness Programme, 2017). General anaesthesia can be offered, but it is operational in coordination with an anaesthetic team in St Columcille's Hospital, which is located about 15 km away from the DDUH. A more comprehensive range of treatment options is available for selection, compared with the service for people with disabilities in Argentina, where inhalation sedation with nitrous oxide is not offered in dental clinics, and intravenous sedation requires an anaesthesiologist to administer (Norderyd et al., 2018). However, other alternative conscious sedation techniques are not available for selection, such as intranasal sedation with midazolam (Wood, 2011) or inhalation sedation with sevoflurane (Allen & Thompson, 2014; Kim & Kim, 2021). The effect of available treatment modalities is similar to a study in Scotland, which revealed that the nature of the clinical setting between a centre with and without a GA facility could influence the decision on the choice of anaesthetics (Sammut et al., 2013).

In Ireland, a medical card scheme is a state-funded program that offers a range of free health services in primary, community, and hospital care, including an annual dental examination, tooth fillings, extractions, and emergency treatment (Citizens Information Board, 2022). Most patients with disabilities who attend the SCD clinic are eligible for medical card holders. Free dental services are available for medical card holders through the Dental Treatment Service Scheme at local HSE services (Health Service Executive). The DDUH can provide free dental

services for medical card holders who reside in Dublin, Wicklow, and Kildare, with the exception of orthodontics, dental implants, cone-beam computed tomography, bone grafts, bleaching trays, and mouthguards. People who reside in other counties require financial approval from their principal dental surgeons of the region prior to qualification (Dublin Dental University Hospital). Although the survey in 2015 showed that only 69% of eligible people applied for the medical card, the medical card scheme can excellently improve healthcare accessibility by removing a financial barrier (Keane et al., 2021). It is apparent that financial restriction could affect accessibility, acceptance, and provision of dental care for people with disabilities, on both patients (Boyle & Lane, 2020) and dentists' aspects (Faulks et al., 2023). The financial situation is one of essential variables to be considered in clinical reality (Croskerry, 2009), but this seemed to have minimal impacts on decision-making in this study due to the local support by the Irish health service system of the medical card scheme.

6.9 Considerations regarding Study Sample

Because this was the first study to explore the accuracy of predicting treatment modalities in SCD, there was no evidence to guide an adequate sample size properly. According to the pilot study, the estimated sample size was calculated as a minimum of 472 cases. However, this was impractical due to the academic timetable. The whole population during the 2-year period from January 2020 to December 2021 was then designed to be included. Apart from the course duration of the postgraduate training of the principal author, the mentioned period was chosen because of two major reasons: recentness and completeness. Because treatment planning characteristics can be affected by several reasons, including the attitude of dental staff and availability of the service (Mac Giolla Phadraig et al., 2022a), freshness of data was therefore prioritised to avoid outdated data, follow the recent global trends and knowledge, and to provide benefits in an immediate effect after completion. The chosen period also allowed time for the overall process of treatment, from acceptance to discharge, to be accomplished. Considering these two criteria, the patients who were accepted into the SCD clinic from January 2020 to December 2021 were verifiably suitable for the study. However, re-assessment cases that were internally assessed before this period were excluded despite

new referrals. Data was set to be collected on their first DDUH visits only. On the other hand, new cases in the chosen period with a history of sedation or GA somewhere else were included due to the set criteria. Previous adjunct use, especially by the in-house specialist team, could influence the selection of treatment modality. Future studies should re-consider the criteria of these particular cases.

Unfortunately, the chosen period is unavoidably affected by the outbreaks of COVID-19, the pandemic disease caused by the novel human coronavirus, namely a severe acute respiratory syndrome coronavirus 2 or SARS-CoV-2. The service all over the globe had been temporarily suspended in order to reduce the transmission of the disease. Only emergency and urgent matters, such as uncontrolled bleeding, facial swelling, trauma, and severe dental pain, were available to the public. During that period, all elective treatments required indefinite deferral (Falahchai et al., 2020), including the service for people with disabilities in the SCD clinic, DDUH. After months of recovery, the medical service was gradually restored and an enormously increasing number of patients required urgent care. Some healthcare facilities had new rules and regulations which may limit access to healthcare for people with disabilities. The patients needed to wait longer due to the high demand for dental treatment post-pandemic, which led to increased time spent on the waiting list. The size of the waiting list could influence the decisions (McGeown et al., 2022). Therefore, COVID-19 and its effects have had a consequential influence on the SCD service, especially in terms of treatment planning and the availability of healthcare facilities. Decisions made during the affected period may lead to low generalisability of the result.

6.10 Strengths and Limitations

This study has a number of strengths and weaknesses that ought to be considered prior to further interpretation. It was designed as a retrospective chart review of the 2-year period. The first part of this study was planned to gather information and analyse statistical methods. The second part intended to apply knowledge for future clinical implications. This design was most appropriate to the research questions for two reasons.

Firstly, because clinical judgement is a complex adaptive cognitive process with several certain and uncertain factors, the best way to study in this field is to incorporate statistics and evidence-based data and then generate well-designed algorithms or guidelines in order to support future clinical judgement, which can be a helpful aid to personal experience and opinion (Feller et al., 2020).

Secondly, the retrospective design offers strength by immensely diminishing prospective biases in making decisions when the intervention is known (Stenson & Kepler, 2019). It also has numerous advantages, such as financial inexpensiveness, easier access to data in a hospital setting, suitability to cases that require long-term follow-up, exploration of rare occurrences, and generation of hypotheses for future testing (Gearing et al., 2006). However, incomplete documentation can be a main limitation, such as missing charts, unrecorded data, difficult interpretation, and heterogeneous data according to multiple data recorders (Gearing et al., 2006). There were some missing data in this study, including information from three referral letters and level of dental anxiety. MDAS levels were obtained in only 33 cases (31.13%) of 106 cases. Therefore, the level of dental anxiety was not present as a significant factor when selecting treatment adjuncts as it is in the IOSN (Coulthard, 2013). Due to the methodological limitation, only the most invasive treatment modality was collected, although some cases may require multiple treatment modalities for each particular treatment. Past adjunct use for dental care was not specific to adult services. Also, this study does not include some possible factors that might have some impacts on decision-making process, including number of presenting carers, ability to have blood drawn at medical appointments, distance in km or mile from a patient's address to the hospital, insurance status, and financial burdens (Mac Giolla Phadraig et al., 2022a; Boyle & Lane, 2020).

Regarding the entire weaknesses of this study, the outcome may not yet be universally generalisable. However, this study hopes to provide an insight to the accuracy of treatment adjunct selection and some benefits in how to minimise the inaccurate prediction and improve the accurate prediction. In the future, a larger sample size and a multicentre study are strongly advised to explore the outcome in a bigger picture as well as to lessen the selection bias (Riley

et al., 2024). Other possible centres include service-based-only hospital settings and services where different treatment adjuncts are available. However, collaborating with other centres will add the number of uncontrollably influencing factors that need to be taken into account, which can affect the validity of the multicentred predictive model. A multicentre study will definitely require a larger population. Significant differences among centres will be mainly in providing non-pharmacological behavioural support, inhalation sedation, and IV sedation because they need knowledge and skills in selecting and performing 'dental behaviour support' techniques. A lack of standard across the centres would lead to poor quality of the future study. Lastly, this study suggested that data collection should follow the concept of recentness and completeness, without the effects of COVID-19, in order to explore the validity of the results.

6.11 Implications of the Study

The implications of the findings of this study can be summarised by the following:

- **Clinical**

  First of all, the result of the study indicates excellent previous decision-making performance in treatment adjunct prediction. Still, decision-making could be optimised, leading to efficiency and better patient outcomes. An algorithm built on the optimised prediction model identified in this study can guide more accurate predictions in the future. However, reliability and instability of the model should be explored in order to validate the model (Riley et al., 2023). It may also be validated using a larger sample size and generalised by a multicentre collaborative study. The findings also draw focus on the decision around IV sedation, which was associated with a lower accuracy rate compared to other modalities. Better pre-sedation assessment could hopefully solve this issue. In assessing patients with challenging behaviour or urgent treatment needs, a more individualised plan, as well as a contingency plan, should be made and practised. Maximising accuracy in treatment adjunct prediction will likely improve patients and their care givers' satisfaction, decrease waiting times for treatment, better management, and greater utilisation of clinical and human resources.

- **Research**

  Future study needs to focus on further validation and generalisation of the proposed prediction model. Using a training-testing split method in a larger sample size is recommended. Furthermore, multicentre research is required to be commenced in different centres or populations, ensuring its robustness and adaptability. Guidance in providing IV sedation for dental patients with disabilities may be developed in order for universal use and to improve its practices. Particular attention in future research should be on those in two groups with significant variables that impacted the accuracy, including challenging behaviour and urgency of treatment. An in-depth exploration of assessing these patients may help in understanding the decision-making process and its impacts. Furthermore, future studies may explore the benefits of having accurate treatment adjunct predictions in SCD, particularly dental treatment complexity, previous history of adjunct use, and consent capacity. Finally, future research may focus only on patients with neurodisability because their peers without neurodevelopmental disability or acquired neurological illnesses were always successfully treated with the chosen treatment modalities.

- **Education**

  The study calls for more robust education and training in non-pharmacological behavioural support techniques. This will equip clinicians to handle complex cases without defaulting to pharmacological interventions, which may reduce the need for more invasive methods, such as GA. Improvement in non-pharmacological behavioural support techniques can help increase success rate of sedation and GA, when employing together. Another field of development is to put decision science into dental education in order to improve decision-making skills and develop the level of confidence in managing complex cases by being aware of and accepting uncertainty in dental care.

7. Conclusion

This is the first retrospective study to develop an understanding of the accuracy of treatment modality selection in patients requiring Special Care Dentistry with the availability of four different treatment adjuncts. During 2020-2021, it revealed an excellent accuracy rate of over 90% with a few inaccurate predictions, mostly when IV sedation was predicted. Sedation failure, service availability, and medical complexity were the three main reasons for the modifications of the treatment modalities. According to the regression analysis, the prediction was far less likely to be accurate in the patients who have challenging behaviour and those requiring urgent treatment. Lastly, a proposed prediction model was developed by incorporating three essential factors, including the overall dental treatment plan, the previous history of using treatment adjuncts for dental care, and the capacity assessment. Future studies are needed to validate and generalise the implications of the proposed prediction model. They may include a collaboration with other centres with different treatment modalities available, as well as a larger sample size to test the model using a training-testing split method.

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APPENDIX

Appendix A: Pilot Study

A pilot study is essential in clinical research to inform the feasibility of and methods to be used in a large-scale full study (In, 2017). Nevertheless, the failures to carry out pilot studies are seen as one of the common errors in the conduct of retrospective chart review, where issues can arise in the validity of data, information retrieval, and missing data (Vassar & Holzmann, 2013).

This pilot study, designed immediately after the agreement of the study protocol, successfully secured ethical approval as per *Appendix B*. The feasibility of variable construction, collection, and analysis was explored prior to the main study. Electronic dental records of 39 charts were randomly explored, and their sociodemographic data were recorded. The outcome of interest was the agreement between the predicted treatment adjuncts (Pre-TA) and the actual treatment adjuncts (Act-TA).

The results of the pilot study demonstrated the feasibility of the data operationalisation and abstraction of the main study with some adjustments. The initial criteria for inclusion and exclusion were rigorously tested and agreed for the final criteria used in the main study. In terms of data collection, a few more variables were suggested to be collected as they showed some plausibility to impact the decision-making of treatment modality selection. These included the role of assessors, suggested modalities from the referring person, and the urgency of treatment mentioned in the referral letters. The Act-TA variable was refined to record only when the dental treatment was possible or achieved, ensuring the accuracy of the data. Lastly, to allow convenience in data collection, the data of patients with multiple visits were recorded for the first four visits only. The accuracy rate was 92.3%, with a 7.7% false prediction rate, which could assist the power calculation of the study.

The pilot study was accepted to be presented as a poster at the biannual conference in Special Care Dentistry held by the International Association for Disability and Oral Health (iADH), in Paris, France, in August 2022. Figure 10 shows a picture of the poster presentation of this pilot study.

Figure 10: A poster presentation of the pilot study, presented at the iADH Paris 2022

How Accurate is Treatment Adjunct Selection in Special Care Dentistry? : A Pilot Study

Poster No.110

panupol.kunasarapun@dental.tcd.ie

Panupol KUNASARAPUN[1,2], Alison DOUGALL[1], Blánaid DALY[1], Erica DONNELLY-SWIFT[1], Caoimhin MACGIOLLA PHADRAIG[1].

[1] Dublin Dental University Hospital, Trinity College Dublin, Ireland
[2] Faculty of Dentistry, Mahidol University, Thailand

Background: Pilot study is essential in clinical research to inform the feasibility of and methods to be used in a large-scale full study[1]. Nevertheless, the failures to carry out pilot studies are seen as common errors in the conduct of retrospective chart reviews, where issues can arise in the validity of data, information retrieval, and missing data[2]. This pilot study informs a retrospective chart review study which aims to determine the accuracy of adjunct selection in patients requiring special care dentistry (SCD). The results of this pilot study are presented here and details of the upcoming a large-scale study are given in a yellow box on the right.

Objectives: To pilot the methods using in the main study by informing sampling approach, variable construction, viability of data collection, and analytic approach.

Methods: Piloting a retrospective chart review design: A data extraction sheet was designed and refined to extract data from thirty-nine randomly selected electronic dental records that met selection criteria (Table 1). This process allowed the team to explore selection criteria, demographic and outcome variable construction, feasibility of data collection, and data analysis plan.

Results:

1. *The pilot study allowed for the following selection decisions:*
   - Initial inclusion and exclusion criteria were tested and agreed for final selection criteria. Unit of analysis was set at the visit rather than patient level. For patients with multiple visits, data will be recorded for the first four visits only. Cases will be selected in one-year strata.
2. *Regarding variables construction:*
   - Categorisation will be informed by WHO's ICD-11 for Mortality and Morbidity Statistics[6]; and by adapting from previous resources[7,8], using 7 categories including physical disability, sensory disability, neurodevelopmental disorder, acquired neurological disorder, medical complexity, psychiatric/emotional disorder, and social exclusion.
   - Adjuncts will be recorded only when the treatment was possible when using the adjunct, not just using it. Multiple approaches to construction were tested.
   - Some variables need to be added because of acting as plausibly significant factors impacting decision-making process which are the need of recording assessor's name, important notes from referral letters (such as suggestion of adjuncts, urgency of treatment).
3. *Regarding feasibility of data collection:*
   - All variables were clarified and instructions for extraction constructed.
4. *Regarding data analysis:*
   - Pilot result displayed 7.7% of false prediction rate (Table 1). This can help designing our data statistical analysis.

Predicted \ Actual	Routine	N_2O	IV	GA
Routine	20			1
N_2O		1		
IV			6	2
GA				9

Table 1

Large-scale study

Background: In SCD, adjuncts are often needed to enable dental care. Broadly, these can be considered as routine care, inhalation sedation, IV sedation and general anaesthesia (GA). The choice between these options represents a complex decision involving many variables and surrounded by uncertainty. When the correct adjunct is assigned, this offers benefits to patient, dental team, and services, as illustrated in Figure 1.

Figure 1

There are some proposed models for adjunct selection such as indicator of sedation need (IOSN)[3], predictor of behaviour in dentistry (PREBED)[4]. However, both models still have unclear predictive value. Therefore, decision making in treatment adjuncts selection must be improved[5]. The large scale study hopes to add to our understanding of this decision by comparing predicted and actual treatment adjuncts used in Special Care Dentistry clinic (Figure 2).

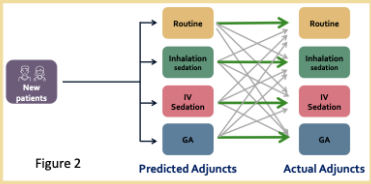

Figure 2

Aims: To investigate the accuracy of predicted versus actual treatment adjuncts used to successfully facilitate care in SCD; and to determine the factors that predict accurate treatment adjuncts selection.

Methods: A 10-year retrospective chart review study was designed. Accuracy will be tested in the main study by comparing the adjunct predicted at assessment visit with the actual adjunct ultimately used for successful treatment. Predictors of accurate selection will also be identified using multiple logistic regression.

Results: We will share the results of this study in IADH conference 2024 in Seoul, South Korea.

Conclusion: The pilot study informed that the main study can proceed with minor changes in methodology and details, especially in terms of data collection process and data analysis. Hopefully, our main study will ultimately lead to improved decision-making, better use of healthcare resources, less inappropriate care, and increased efficiency of assessment.

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Appendix B: Evidence of Ethical Approval of a Pilot Study

Gary Moran

Fri 11/02/2022, 14:54

Caoimhin MacGiolla Phadraig; Alison Dougall; Panupol Kunasarapun

Reply

ALERT: This message originated outside of DDUH's network. **BE CAUTIOUS** before clicking any link or attachment.

Dear Caoimhin,
Thank you for your correspondence regarding the pilot chart review. As arrangements are in place in DDUH to inform patients that their chart data may be used in anonymous research, as per the Health Research regulations, this type of research is permissible. On this basis and on behalf of the committee, I am willing to grant permission for a small pilot exercise to be carried out prior to the submission of a full proposal for ethical approval for a larger study,

sincerely,
Gary Moran
Chair DSREC

Appendix C: Evidence of Ethical Approval of the Main Study

Re: REC submission

Gary Moran
Mon 16/01/2023 13:10
To: Panupol Kunasarapun
Cc: Caoimhin MacGiolla Phadraig; Alison Dougall

Reply

Inbox

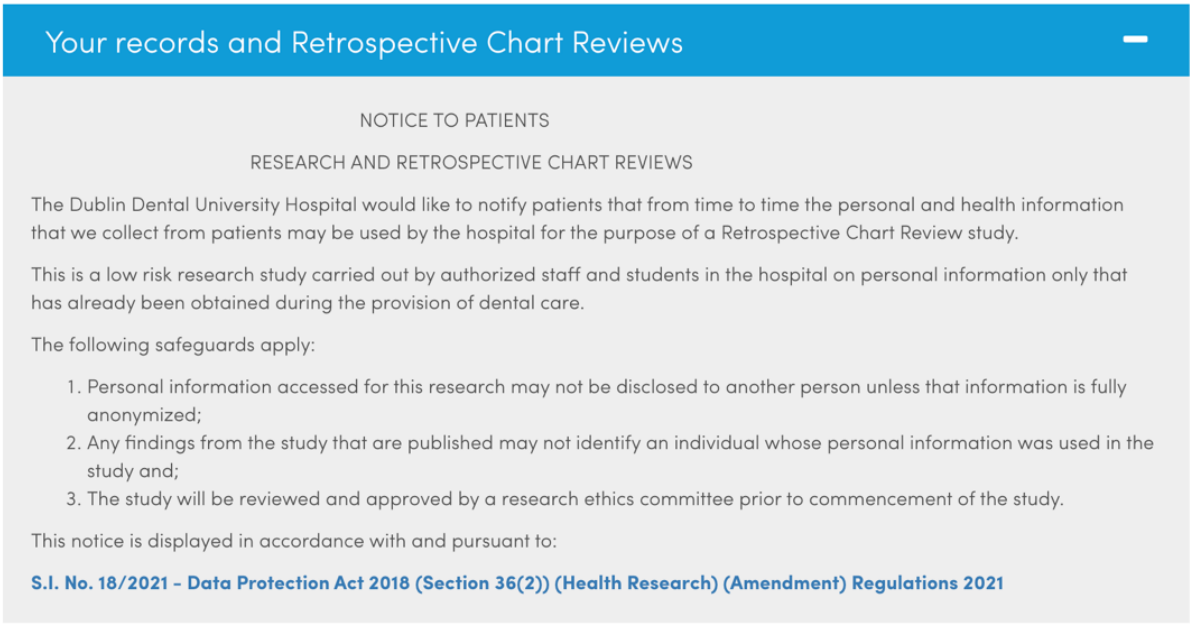
Dear Panupol,
Apologies for the delay in reviewing your resubmission. I can see that you have clearly addressed all of the comments raised by the reviewers. On behalf of the committee I am willing to grant approval for this project to proceed. Please use the number DSREC2023/01 in future correspondence,

Sincerely,
Gary Moran
DSREC Chair

--
Dr. Gary Moran
Dublin Dental University Hospital

Appendix D: Notice to Patients regarding Research and Retrospective Chart Reviews

The following pictures are the notice to the patients regarding the use of their records may be used for research and retrospective chart reviews. The notices have been posted on the website (https://www.dentalhospital.ie/about/data-protection/privacy-notice) and on the board at the West Clinic, where the SCD clinic takes place.



Your records and Retrospective Chart Reviews

NOTICE TO PATIENTS

RESEARCH AND RETROSPECTIVE CHART REVIEWS

The Dublin Dental University Hospital would like to notify patients that from time to time the personal and health information that we collect from patients may be used by the hospital for the purpose of a Retrospective Chart Review study.

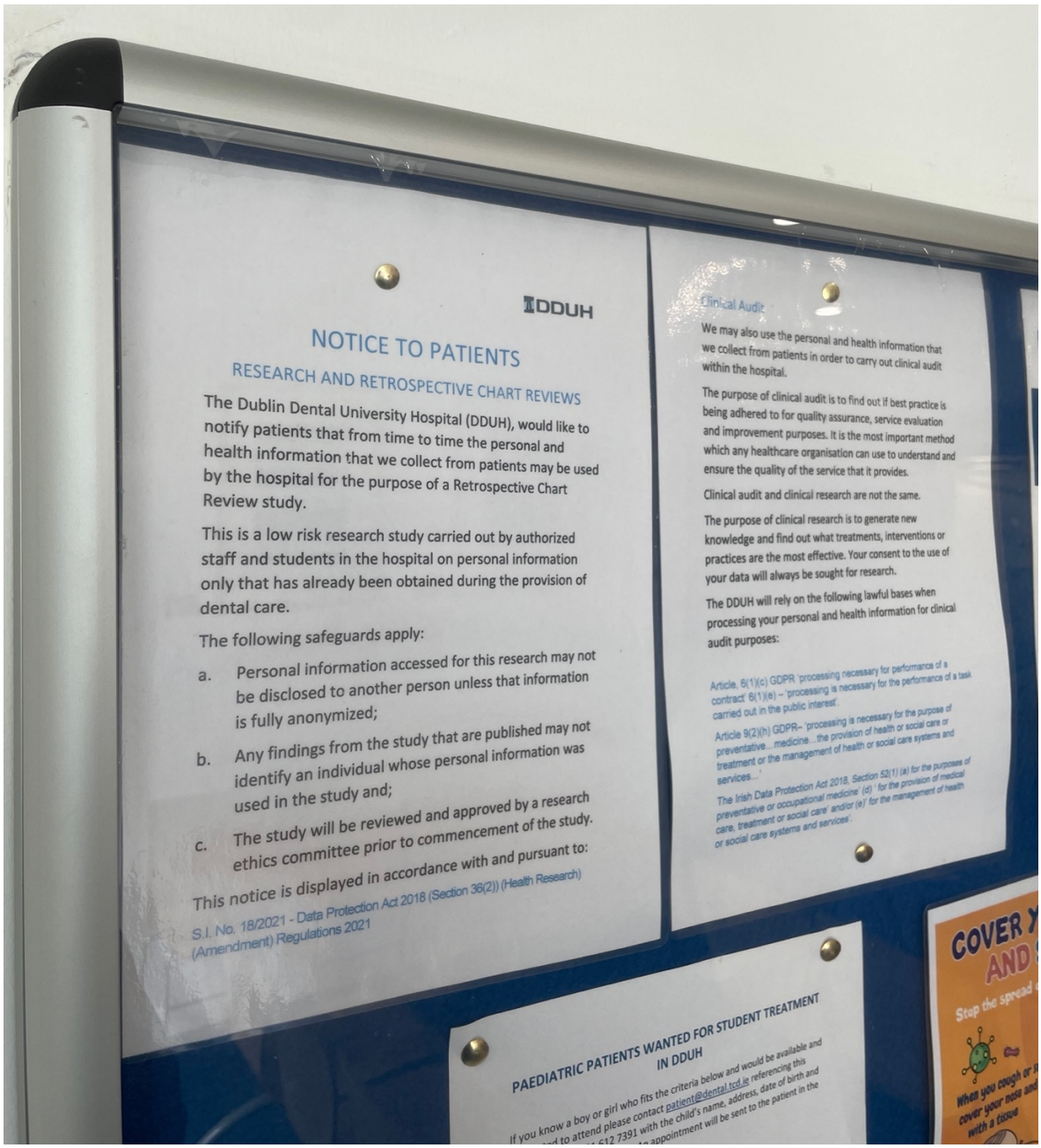
This is a low risk research study carried out by authorized staff and students in the hospital on personal information only that has already been obtained during the provision of dental care.

The following safeguards apply:

1. Personal information accessed for this research may not be disclosed to another person unless that information is fully anonymized;
2. Any findings from the study that are published may not identify an individual whose personal information was used in the study and;
3. The study will be reviewed and approved by a research ethics committee prior to commencement of the study.

This notice is displayed in accordance with and pursuant to:

S.I. No. 18/2021 - Data Protection Act 2018 (Section 36(2)) (Health Research) (Amendment) Regulations 2021



DDUH

NOTICE TO PATIENTS

RESEARCH AND RETROSPECTIVE CHART REVIEWS

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This is a low risk research study carried out by authorized staff and students in the hospital on personal information only that has already been obtained during the provision of dental care.

The following safeguards apply:

a. Personal information accessed for this research may not be disclosed to another person unless that information is fully anonymized;

b. Any findings from the study that are published may not identify an individual whose personal information was used in the study and;

c. The study will be reviewed and approved by a research ethics committee prior to commencement of the study.

This notice is displayed in accordance with and pursuant to:

S.I. No. 18/2021 - Data Protection Act 2018 (Section 36(2)) (Health Research) (Amendment) Regulations 2021

Clinical Audit

We may also use the personal and health information that we collect from patients in order to carry out clinical audit within the hospital.

The purpose of clinical audit is to find out if best practice is being adhered to for quality assurance, service evaluation and improvement purposes. It is the most important method which any healthcare organisation can use to understand and ensure the quality of the service that it provides.

Clinical audit and clinical research are not the same.

The purpose of clinical research is to generate new knowledge and find out what treatments, interventions or practices are the most effective. Your consent to the use of your data will always be sought for research.

The DDUH will rely on the following lawful bases when processing your personal and health information for clinical audit purposes:

Article, 6(1)(c) GDPR 'processing necessary for performance of a contract' 6(1)(e) – 'processing is necessary for the performance of a task carried out in the public interest'.

Article 9(2)(h) GDPR– 'processing is necessary for the purpose of preventative…medicine…the provision of health or social care or treatment or the management of health or social care systems and services…'

The Irish Data Protection Act 2018, Section 52(1) (a) for the purposes of preventative or occupational medicine' (d) ' for the provision of medical care, treatment or social care' and/or (e)' for the management of health or social care systems and services'.

PAEDIATRIC PATIENTS WANTED FOR STUDENT TREATMENT IN DDUH

If you know a boy or girl who fits the criteria below and would be available and ...d to attend please contact patient@dental.tcd.ie referencing this ... 612 7391 with the child's name, address, date of birth and ... appointment will be sent to the patient in the

COVER Y... AND ...

Stop the spread ...

When you cough or ... cover your nose and ... with a tissue

Appendix E: Approval of the Data Protection Impact Assessment (DPIA)

DDUH

Data Protection Impact Assessment (DPIA) Template – Research

Purpose of a DPIA
The purpose of a DPIA is to assess and demonstrate compliance with data protection legislation. The DPIA also provides evidence that the risks to individuals have been considered and sufficient measures have been taken to protect those individuals. The DPIA should assess the activity to be carried out against all the principles of data protection and determine whether the processing of personal data is both necessary and proportionate or whether changes to the process or additional controls are required.

It is important to note that a DPIA is required as standard for research studies conducted at St. James's Hospital, Tallaght University Hospital and all clinical sites in which DDUH researchers are active. Each site will require its own DPIA.

Study Name: Accuracy of predicting treatment adjuncts for patients requiring special care dentistry (SCD)	**Date:** 26 October 2022
Owner: Panupol Kunasarapun (Post-graduate) Dr Caoimhin MacGiolla Phadraig Prof Alison Dougall	**Site:** Dublin Dental University Hospital (DDUH)
Email: Panupol.kunasarapun@dental.tcd.ie	**Phone Number:** 0830880259

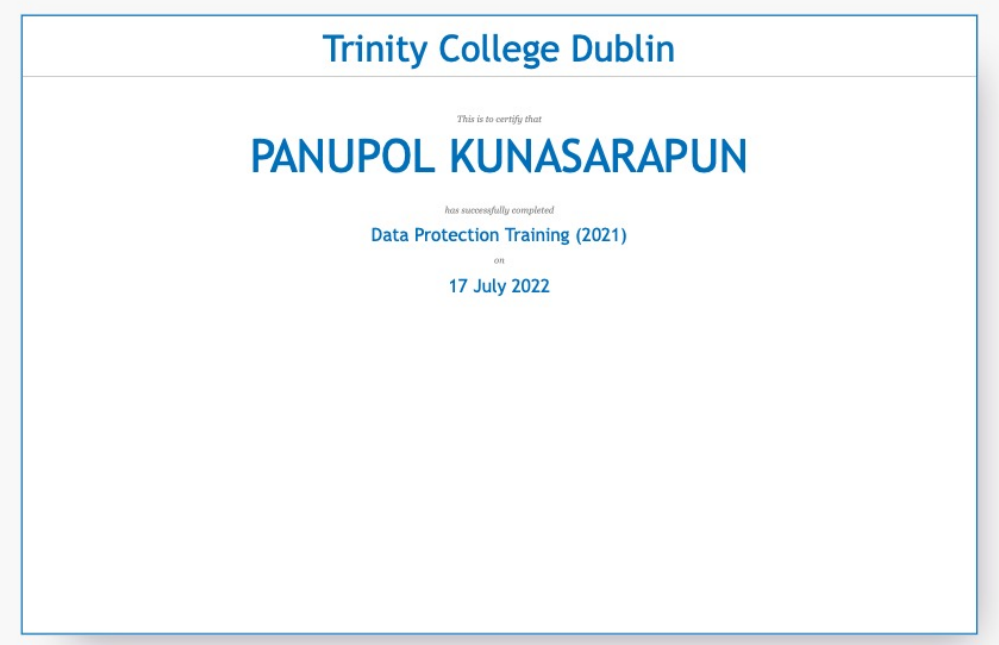
Template Version Control

Reference	Date	Author	Comments
1.0	June 2020	DDUH DPO	

DPIA Circulation

Name	Date	Reviewed/Consulted
PI Details Panupol Kunasarapun	26 October 2022	*Reviewed/Consulted*
Co-I/Other Details Dr Caoimhin MacGiolla Phadraig Prof Alison Dougall	26 October 2022	*Reviewed*
DPO Details Colette Kinsley	08.11.22[Insert Date]	*Reviewed/Consulted*

Appendix F: Data Protection Training Certificate



Appendix G: Programme Coding

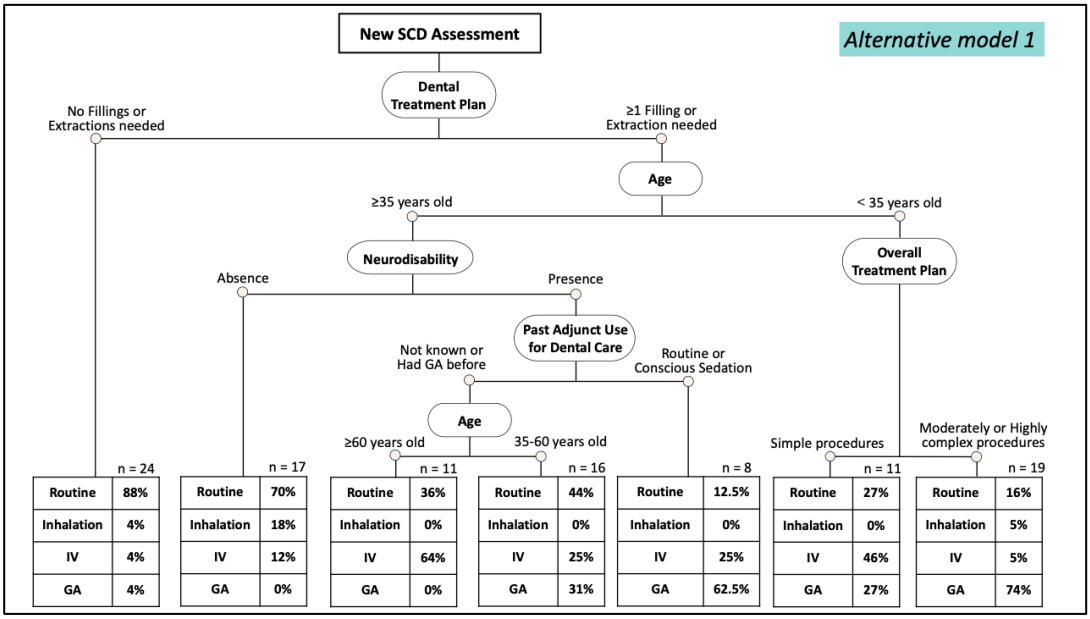
```
R version 4.3.2 (2023-10-31) -- "Eye Holes"
Copyright (C) 2023 The R Foundation for Statistical Computing
Platform: x86_64-pc-linux-gnu (64-bit)

> install.packages("csv")
Installing package into ‘/cloud/lib/x86_64-pc-linux-gnu-library/4.3’
(as ‘lib’ is unspecified)
also installing the dependencies ‘data.table’, ‘stringi’

trying URL 'http://rspm/default/__linux__/focal/latest/src/contrib/data.table_1.15.
0.tar.gz'
Content type 'application/x-gzip' length 2194206 bytes (2.1 MB)
==================================================
downloaded 2.1 MB

trying URL 'http://rspm/default/__linux__/focal/latest/src/contrib/stringi_1.8.3.ta
r.gz'
Content type 'application/x-gzip' length 4314955 bytes (4.1 MB)
==================================================
downloaded 4.1 MB

trying URL 'http://rspm/default/__linux__/focal/latest/src/contrib/csv_0.6.2.tar.gz
'
Content type 'application/x-gzip' length 25062 bytes (24 KB)
==================================================
downloaded 24 KB

* installing *binary* package ‘data.table’ ...
* DONE (data.table)
* installing *binary* package ‘stringi’ ...
* DONE (stringi)
* installing *binary* package ‘csv’ ...
* DONE (csv)

The downloaded source packages are in
        ‘/tmp/RtmpiR5PGt/downloaded_packages’
> Data <- read.csv("pf5.csv", header=TRUE)
> View(Data)
> Data <- Data[,-1]
> Data <- Data[,-1]
> Data <- na.omit(Data)
> cols <- c(1:17)
> Data[cols] <- lapply(Data[cols],factor)
> str(Data)
'data.frame':    106 obs. of  17 variables:
 $ Assessor_role        : Factor w/ 4 levels "1","2","3","4": 2 2 3 3 3 3 3 3 4 3 .
..
 $ Pre_TA               : Factor w/ 4 levels "1","2","3","4": 1 1 1 4 3 3 3 4 1 1 .
..
```

```
 $ Act_TA               : Factor w/ 4 levels "1","2","3","4": 1 1 1 4 4 3 3 4 1 1 .
..
 $ Age_group            : Factor w/ 3 levels "1","2","3": 1 2 3 1 3 2 3 1 2 3 ...
 $ ChalBeh              : Factor w/ 2 levels "0","1": 1 1 1 2 2 1 1 2 1 1 ...
 $ Non.verbal           : Factor w/ 2 levels "0","1": 1 2 1 2 1 1 2 1 1 1 ...
 $ Consent.Assent       : Factor w/ 2 levels "1","2": 1 2 1 2 2 2 2 1 1 1 ...
 $ AnyNeuroDisability   : Factor w/ 2 levels "0","1": 2 2 2 2 2 2 2 2 1 1 ...
 $ County_distance      : Factor w/ 4 levels "1","2","3","4": 2 2 1 1 1 1 1 3 1 1 .
..
 $ County_distance2     : Factor w/ 2 levels "1","2": 1 1 1 1 1 1 1 2 1 1 ...
 $ PDHx                 : Factor w/ 5 levels "0","1","2","3",..: 2 1 1 1 2 1 1 2 1
2 ...
 $ PDHx_success_faiilure: Factor w/ 3 levels "0","5","6": 2 1 1 1 3 1 1 2 1 2 ...
 $ UDA                  : Factor w/ 31 levels "2","3","4","5",..: 2 3 3 5 12 16 6 2
6 31 29 ...
 $ UDA_group            : Factor w/ 3 levels "1","2","3": 1 1 1 1 2 2 1 3 3 3 ...
 $ Extraction_yesno     : Factor w/ 2 levels "0","1": 1 1 2 1 2 2 2 2 2 2 ...
 $ Filling_number       : Factor w/ 4 levels "0","1","2","3": 1 1 1 1 1 1 1 4 4 1 .
..
 $ Filling_regroup      : Factor w/ 4 levels "0","1","2","E": 1 1 4 1 4 4 4 3 3 4 .
..
 - attr(*, "na.action")= 'omit' Named int [1:14] 107 108 109 110 111 112 113 114 11
5 116 ...
  ..- attr(*, "names")= chr [1:14] "107" "108" "109" "110" ...
> summary(Data$AGREEMENT)
Length  Class   Mode
     0   NULL   NULL
> summary(Data$Pre_TA)
 1  2  3  4
49  5 29 23
> summary(Data$ChalBeh)
 0  1
85 21
> library(rpart)
> install.packages ("partykit")
Installing package into ‘/cloud/lib/x86_64-pc-linux-gnu-library/4.3’
(as ‘lib’ is unspecified)
also installing the dependencies ‘libcoin’, ‘mvtnorm’, ‘Formula’, ‘inum’

trying URL 'http://rspm/default/__linux__/focal/latest/src/contrib/libcoin_1.0-10.t
ar.gz'
Content type 'application/x-gzip' length 807470 bytes (788 KB)
==================================================
downloaded 788 KB

trying URL 'http://rspm/default/__linux__/focal/latest/src/contrib/mvtnorm_1.2-4.ta
r.gz'
Content type 'application/x-gzip' length 746121 bytes (728 KB)
==================================================
downloaded 728 KB

trying URL 'http://rspm/default/__linux__/focal/latest/src/contrib/Formula_1.2-5.ta
r.gz'
```

```
Content type 'application/x-gzip' length 158353 bytes (154 KB)
==================================================
downloaded 154 KB

trying URL 'http://rspm/default/__linux__/focal/latest/src/contrib/inum_1.0-5.tar.g
z'
Content type 'application/x-gzip' length 36633 bytes (35 KB)
==================================================
downloaded 35 KB

trying URL 'http://rspm/default/__linux__/focal/latest/src/contrib/partykit_1.2-20.
tar.gz'
Content type 'application/x-gzip' length 2414010 bytes (2.3 MB)
==================================================
downloaded 2.3 MB

* installing *binary* package ‘mvtnorm’ ...
* DONE (mvtnorm)
* installing *binary* package ‘Formula’ ...
* DONE (Formula)
* installing *binary* package ‘libcoin’ ...
* DONE (libcoin)
* installing *binary* package ‘inum’ ...
* DONE (inum)
* installing *binary* package ‘partykit’ ...
* DONE (partykit)

The downloaded source packages are in
        ‘/tmp/RtmpiR5PGt/downloaded_packages’
> attach(Data)
> library(partykit)
Loading required package: grid
Loading required package: libcoin
Loading required package: mvtnorm
> DT_Model <-rpart (Act_TA ~ Assessor_role + Age_group + ChalBeh + Non.verbal + Con
sent.Assent + AnyNeuroDisability + County_distance + County_distance2 + PDHx + PDHx
_success_faiilure + UDA_group + Extraction_yesno + Filling_regroup)
> plot(as.party(DT_Model))
> DT_Model2 <-rpart (Act_TA ~ Consent.Assent + PDHx + UDA_group + Extraction_yesno
+ Filling_regroup)
> plot(as.party(DT_Model2))
> DT_Model3 <-rpart (Act_TA ~ Age_group + ChalBeh + Non.verbal + Consent.Assent + A
nyNeuroDisability + PDHx + UDA_group + Extraction_yesno + Filling_regroup)
```

Appendix H: Alternative Models

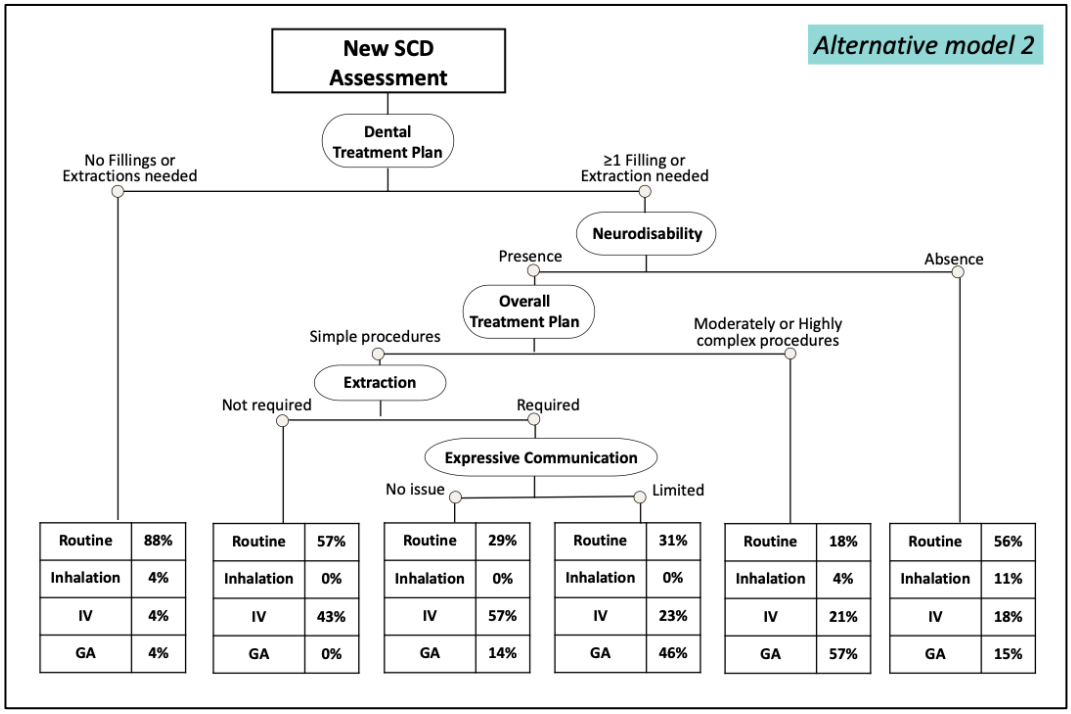
Figure 11: Alternative model 1



Similar to the proposed model, this alternative model employed the dental treatment plan and the history of using treatment adjuncts for dental care. Nonetheless, instead of the capacity to consent, it included the presence of neurodisability and age in the decision-making process. In an absence of neurodisability, the model suggests a 70% chance of using routine as a successful treatment adjunct. In comparison, another 30% chance of using conscious sedation is displayed, while GA is not suggested in this cohort. A cut-point of 35 years old was used in the model.

Interestingly, it highlighted the concept of treatment in people in their old age by avoiding the use of GA to prevent the risk of postoperative cognitive decline (Belrose & Noppens, 2019; Vacas et al., 2021). Regarding the patients with neurodisability who required at least a filling or an extraction neurodisability, IV sedation is suggested with over 60% probability to be a successful treatment adjunct if they are older than 60 years old. This alternative model was not chosen because it showed no clinical relevance to include patients with their past adjuncts were unknown, together with those who had GA for dental treatment. Also, it was too complex to be implemented as it required up to five steps of the decision-making process in some nodes.

Figure 12: Alternative model 2



Here is another alternative model, which was not selected to be a proposed model. This model comprised four different factors to be considered, including the dental treatment plan, the presence of neurodisability, the need for tooth extraction, and expressive communication issues. This model highlighted that GA should never be required if there is no tooth extraction planned in patients with neurodisability and their overall treatment plan is simple. Moreover, there is a difference in the suggestions for successful treatment adjunct uses in patients with and without expressive communication problem. Apart from routine, IV sedation shows a higher probability than GA in patients with no communication issues, whereas GA has a higher chance of success in being selected in patients with limited expressive communication. Again, this model was not chosen because of some clinical irrelevance, complexity in the decision-making process, and dependency on the dental treatment plan.