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Why and When Are Evidence-Based Interventions Adopted in Paediatric Supportive Care? A Qualitative Exploration of the Determinants of Photobiomodulation Implementation

Claudia Heggie[1] | Kara A. Gray-Burrows[2] | Peter F. Day[3] | Bob Phillips[4] | Carl A. Thompson[5]

[1]Paediatric Dentistry, School of Dentistry, University of Leeds, Leeds, UK | [2]Behavioural Sciences & Complex Intervention Methodology, School of Dentistry, University of Leeds, Leeds, UK | [3]Children's Oral Health & Paediatric Dentistry, School of Dentistry, University of Leeds and Community Dental Service, Leeds, Bradford District Care NHS Foundation Trust, Bradford, UK | [4]Paediatrics and Evidence Synthesis & Paediatric Oncology, University of York, York, UK | [5]Applied Health Research, School of Healthcare, University of Leeds, Leeds, UK

Correspondence: Claudia Heggie (C.Heggie@leeds.ac.uk)

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ABSTRACT

Background: Oral mucositis is a common and debilitating side effect of childhood cancer and stem cell transplant treatments. It affects the quality of life of children and young people (CYP) and places a strain on services. Photobiomodulation is recommended for oral mucositis prevention in international guidance but is poorly implemented in UK Principal Treatment Centres (PTCs). Our study explored the key barriers and facilitators to implementing photobiomodulation into standard care.

Methods: CYP, their parents, and healthcare professionals (HCPs) were purposively sampled for diversity in theoretically important characteristics: stage of adoption of PTC, professional role (HCPs), age (CYP), and photobiomodulation modality. Initial deductive framework analysis on semi-structured interview data was guided by the Consolidated Framework for Implementation Research (CFIR). Qualitative summaries were then inductively generated, articulating the valence of influence and effect. Overarching themes were developed and refined in collaboration with patient involvement groups.

Results: Twenty-seven participants were interviewed: 18 HCPs from 11 diverse PTCs, 1 industry representative, and 4 CYP/Parent dyads. Participants had experience with low-level laser ($n = 15$) and light-emitting diode (LED) ($n = 13$) systems. Perceived barriers and facilitators varied between PTCs, participant groups, and photobiomodulation systems. Five themes were developed: (1) framing photobiomodulation as essential to routine care in busy cancer services; (2) photobiomodulation as simple, proactive, and rewarding; (3) need for navigable, interconnected, multiprofessional networks to support implementation; (4) balancing individualisation of services with the need for guidance and standardisation; and (5) increasing implementation of LED systems, with fewer barriers, over time.

Conclusion: Implementing photobiomodulation in paediatric oncology depends less on its clinical evidence and more on the local conditions that enable reliable delivery. This study highlights the importance of aligning service structures, workforce capacity, and professional networks to 'embed' photobiomodulation as routine care. Theory-informed implementation strategies can reduce current inequities in access and provide a transferable model for introducing other evidence-based supportive care interventions.

Abbreviations: CFIR, Consolidated Framework for Implementation Research; CYP, Children and young people; ERIC, Expert Recommendations for Implementing Change; HCPs, Healthcare professionals; HSCT, Haematopoietic stem cell transplant; LED, Light-emitting diode; NHS, National Health Service; PPI, Patient and Public Involvement; PTC, Principal Treatment Centre.

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1 | Introduction

Oral mucositis is a common complication of cancer and haematopoietic stem cell transplant (HSCT) treatment, affecting over half of all children and young people (CYP) receiving chemotherapy [1]. Severe cases substantially reduce quality of life, limiting eating, drinking, swallowing, communication, and sleep [2]. These effects disrupt children's sense of normality and add pressure to healthcare services managing pain, nutrition, and unplanned admissions [3–5].

Photobiomodulation (PBM) – the application of low-power visible red or near-infrared light to stimulate tissue repair [6] – can prevent oral mucositis. Delivered using low-level laser or light-emitting diode (LED) systems during chemotherapy, PBM halves the incidence of severe oral mucositis [7, 8]. Consequently, international supportive care guidance recommends prophylactic PBM for CYP undergoing HSCT or at high risk of mucositis [9, 10].

Earlier concerns about the acceptability of PBM to CYP [9] have been challenged by recent qualitative work showing it to be well tolerated, child-friendly, and viewed as effective and of low opportunity cost [11]. Despite strong evidence of effect and positive perceptions, PBM remains poorly implemented across UK paediatric cancer services [12]. Early studies highlight limited skills and knowledge in PBM and its delivery, and uncertainty surrounding professional roles and responsibilities [12]. In addition, implementation leads at early adopting sites were commonly dental clinicians, who are not embedded into the work infrastructure of the majority of children's cancer services.

Although use of PBM is gradually increasing, adoption remains confined largely to major cancer centres, creating geographic inequities and the risk of widening health disparities. Implementation science provides a framework for understanding and addressing such gaps by examining how context, behaviour, and organisational factors influence uptake of evidence-based care [13].

This study applies a determinant framework grounded in implementation science to identify key influences on PBM adoption across Principal Treatment Centres (PTCs) in the United Kingdom and Ireland. By analysing how and why implementation succeeds or stalls in different contexts, we aim to inform the development of transferable, theory-driven strategies for wider adoption and sustainable integration into paediatric supportive care [14].

2 | Methods

2.1 | Study Design

This qualitative study used semi-structured interviews with healthcare professionals (HCPs), CYP with cancer, and their parents. Reporting follows the Consolidated Criteria for Reporting Qualitative Studies (COREQ) [15]. Ethical approval was granted by the NHS Health Research Authority (24/YH/0080), with the University of Leeds as sponsor. This qualitative study represents the first research phase of the National Institute for Health and Care Research (NIHR) funded SPOT-LITE study, which aims to increase the uptake of PBM in UK paediatric cancer and stem cell transplant centres (ISRCTN12589862).

2.2 | Patient and Public Involvement

Children with cancer and their families were involved throughout, with matched funding and support provided by Candlelighters Children's Cancer Charity (Registered Charity 1045077). They contributed to research prioritisation and design of participant information materials at the grant application stage and later supported analysis and refinement of themes following qualitative methods training. Findings will be shared through the Candlelighters Supportive Care Research Centre at the University of York, family networks, and future involvement meetings.

2.3 | Setting

Interviews were conducted online or at the Candlelighters family support centre. Participants were drawn from 21 PTCs for childhood cancer in the United Kingdom and Ireland [16], reflecting either provider (healthcare professional) or patient/family perspectives. These services are commissioned nationally, at the level of the devolved nations for the United Kingdom.

2.4 | Participants and Sampling

Sampling was theoretically informed to capture determinants of implementation. Rogers theorised adoption to follow an S-shaped curve when mapping the proportion of intervention adoption in a given setting and time elapsed [17]. PTCs were therefore mapped against this curve, and the centre PBM adoption stage was categorised as early adopter, early majority, or peri-implementation.

Eligible professionals included those involved in PBM implementation or delivery, and wider NHS stakeholders (e.g., commissioners and industry partners). Purposive sampling sought variation by PTC adoption stage, geography, professional role, and PBM system experience (LED or low-level laser). Professionals were recruited via email and snowball sampling. Non-adopting PTCs, with no plans to establish PBM services, were excluded from sampling as professionals at these centres were unlikely to be able to meaningfully engage with implementation theory-driven interviews on highly specific subject matter, and would yield data of low information power [18].

Families were recruited through regional charity networks in Leeds, Edinburgh, and Sheffield. Sampling aimed for diversity in child age, cancer diagnosis, and PBM experience. Inclusion criteria were CYP aged 6–17 years old with sufficient English proficiency to participate meaningfully in qualitative interviews [3, 11].

All participants received a £25 voucher in recognition of their contribution. Recruitment and analysis proceeded concurrently until information power was achieved [18]. Given the narrow study focus and theoretically informed sampling, the anticipated sample size was 15–20 professionals and 4–5 CYP/parent dyads

to meet this criterion. This was supported by previous experiences in conducting qualitative research regarding PBM in this population, and the number of participants required to reach information power in these studies [3, 11].

2.5 | Data Collection and Analysis

2.5.1 | Theoretical Frameworks

The updated Consolidated Framework for Implementation Research (CFIR 2.0) provided the theoretical foundation for study design and analysis [19]. Derived from 19 established implementation models [20] and refined through systematic review and user feedback, the CFIR comprises 48 constructs within five domains: innovation characteristics, outer setting, inner setting, roles and characteristics of individuals, and implementation processes. The CFIR provides a theoretical lens through which to examine barriers and facilitators to the adoption of interventions.

Expert Recommendations for Implementing Change (ERIC) have been mapped to CFIR constructs in a consensus study, aiming to guide clinicians to evidence-based strategies most likely to overcome identified implementation barriers in their context [21]. This provides a research-driven approach to the identification and navigation of contextual barriers.

Topic guides were developed from the updated CFIR and literature review, then iteratively refined as analysis progressed.

2.6 | Data Collection

Interview schedules for HCPs explored implementation experiences, service organisation, and contextual barriers and facilitators. Probes were phrased in concrete terms for PTCs with an established service and in speculative terms for those in peri-implementation sites. For CYP–parent dyads, interviews focused on experiences of receiving PBM, perceptions of the intervention, and its integration within standard care pathways.

Semi-structured interviews were conducted either online, or face-to-face at the University of Leeds (professionals) or the Candlelighters family support centre (families). Two researchers (CH, a paediatric dentistry clinical academic, and BP, a senior paediatric oncology clinical academic) jointly conducted CYP–parent interviews to ensure safeguarding. Professional interviews were conducted by CH alone to minimise hierarchical bias.

CYP were interviewed alongside parents to enable shared reflection and support understanding. A safeguarding protocol with escalation and signposting procedures was in place. Families had experience with either LED or laser PBM systems; the alternative system was described using standardised information and clinical images.

Demographic information relevant to purposive sampling was recorded. All interviews were audio-recorded, professionally transcribed, and verified for accuracy by the lead researcher. Field notes were integrated into the analysis.

2.7 | Data Analysis

Analysis followed a hybrid deductive-inductive approach using CFIR 2.0 [19] within NVivo (NVivo 15.1.1, Lumivero) to support data management and coding. Data were coded line-by-line to CFIR constructs, and within-construct summaries were developed through constant comparison. Overarching themes were then inductively generated across domains. This approach supported the application of established theory whilst allowing for novel insights to be generated from the data. Each construct was assigned a valence rating to denote its direction and strength of influence on implementation (e.g., ++ strong facilitator; – weak barrier; +/- bidirectional), in line with CFIR recommendations for qualitative analysis [22]. Ratings were determined by the lead researcher based on influence, frequency, feasibility, data source, and patient–public input.

Interpretation and boundary definition of CFIR domains were reviewed collaboratively with an experienced qualitative researcher (KG-B). No repeat interviews or member checking were undertaken to avoid post hoc reinterpretation. Patient and public involvement (PPI) contributors, trained in qualitative methods, participated in interpretation and theme refinement.

2.8 | Mapping to Implementation Strategies

All identified barriers – regardless of strength or valence – were mapped to the ERIC framework [21]. For each CFIR construct, the three most applicable ERIC strategies were reviewed, with one best-fit strategy selected. Where novel CFIR 2.0 constructs (not mapped to ERIC strategies by Waltz et al.) were identified, corresponding strategies were chosen from the broader ERIC compilation to maintain theoretical alignment.

3 | Results

3.1 | Participants

Data collection took place between July and October 2024. Thirty-one HCPs were approached, and five CYP–parent dyads expressed interest in participation. Nineteen professionals and four dyads completed interviews; one family withdrew due to treatment-related illness.

Participants represented diverse professional roles, treatment centres, and experience with both laser and LED PBM systems. Demographic and sampling characteristics for all 27 participants are shown in Figure 1.

Recruitment of families came with challenges. Several expressions of interest were found to contain inaccurate or implausible information, such as rare cancer diagnoses not prevalent in paediatric settings, or reported use of PBM at centres without a service. These cases were excluded as non-genuine participants following verification to ensure data validity and participant authenticity [23].

Professionals worked in 11 different PTCs, with different clinical populations and service structures, and stages of PBM (see

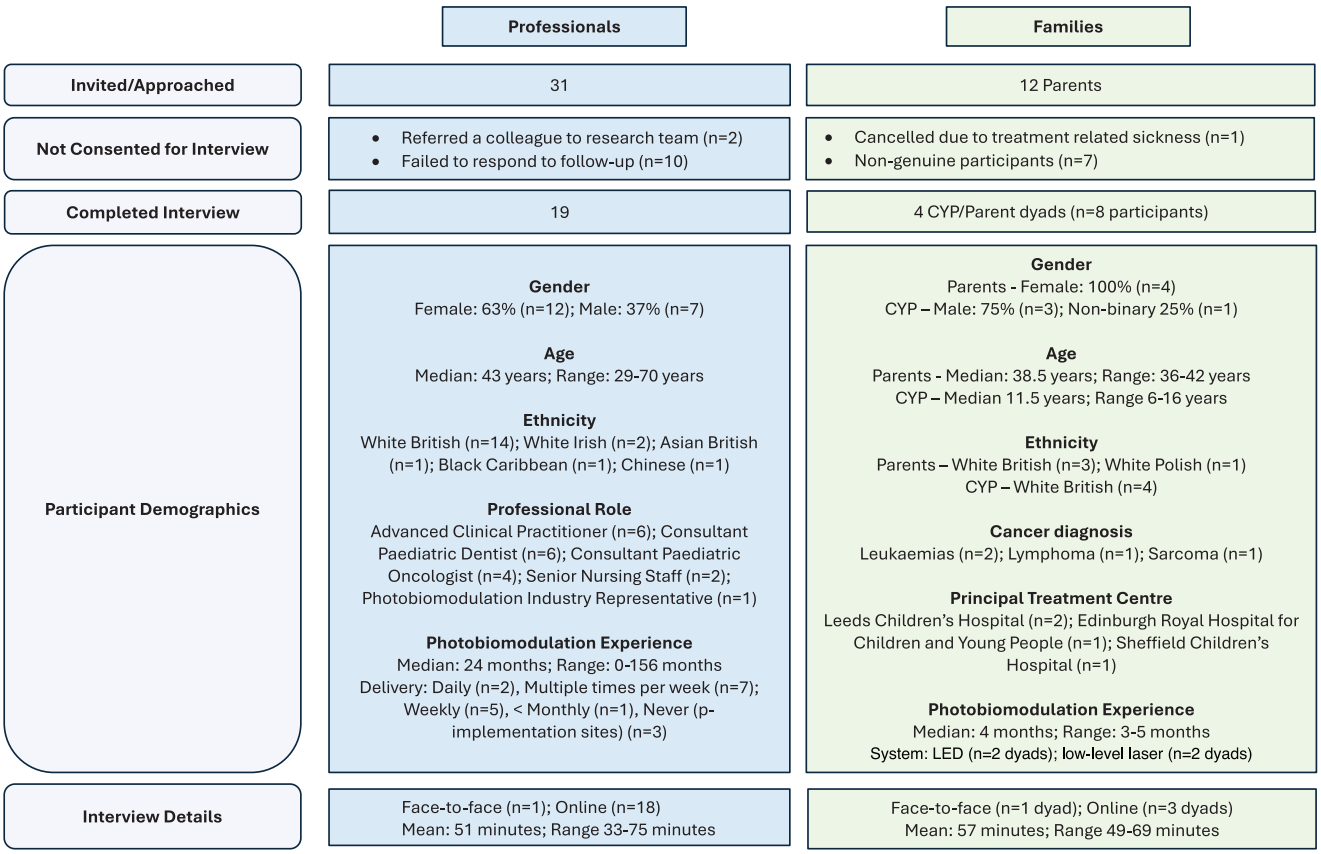

FIGURE 1 | Recruitment flow for semi-structured interviews, participant characteristics, and interview duration for each participant group.

Table 1). One industry representative had experience of both LED and low-level laser systems, through their role in supporting national and international PBM implementation.

Dentists frequently led implementation of PBM services. Where dentists were absent ($n = 2$ centres) or present but not involved in PBM adoption ($n = 2$ centres), implementation leads were most frequently Advanced Clinical Practitioners within the Haematology/Oncology team, with support from a wider implementation team.

3.2 | Qualitative Analysis

Figure 2 summarises CFIR domains and constructs demonstrating a strong influence on implementation. The *Inner Setting* and *Characteristics of Individuals* emerged as the most influential domains. Inherent *Innovation Characteristics* of PBM acted as strong facilitators, reinforced by professional and organisational connections within the *Outer Setting*. In contrast, *Implementation Processes* varied markedly between PTCs, shaping both the pace and fidelity of adoption.

Five themes were developed from 128 qualitative summaries representing the critical determinants of PBM implementation. Themes are explored below, with highly influential determinants discussed in the text and CFIR constructs highlighted in *italic* typeface and valence in square brackets.

4 | Theme 1. Framing PBM as Essential Within Routine Care in Busy Cancer Services

Data within this theme are primarily related to the *Inner Setting* and *Characteristics of Individuals* domains. Key determinants and illustrative data are summarised in Table 2.

4.1 | Inner and Outer Settings

Oral mucositis was a salient concern for all participant groups, with few effective treatment alternatives. This generated a strong *tension for change* [++] and clear *mission alignment* [++] with PTCs' aims to deliver 'kinder treatments'. In the *Outer Setting*, positive *local attitudes* [+] and *financing* [++] – particularly through charitable funding aligned with quality-of-life improvements – further supported adoption. However, supportive care interventions were generally afforded a lower *relative priority* [−−] than curative treatments within local service agendas.

Participants identified both direct and indirect *incentive systems* [++], including reduced clinical burden from managing severe mucositis and opportunities to reinforce oral health promotion. Yet these potential gains were constrained by limited *available resources* [−−], particularly shortages of PBM trained staff, which was identified as the most significant barrier to implementation fidelity.

TABLE 1 | Characteristics of included PTCs.

Site	Participants ($n = 27$)	PBM type	Location	Recipient groups	Dental team implementation involvement
Early adopters ($n = 3$ PTCs)					
A	3 HCPs 1 CYP/parent dyad	LLLT	Scotland	Oncology	Yes (implementation lead)
B	2 HCPs	LLLT	Scotland	Oncology and HSCT	Yes (implementation lead)
C	1 HCP	LLLT	Republic of Ireland	Oncology and HSCT	Yes (implementation lead)
Early Majority (n = 5 PTCs)					
D	1 HCP	LED	Northern England	Oncology	No (available in PTC)
E	3 HCPs 2 CYP/parent dyads	LED	Northern England	Oncology and HSCT	Yes (implementation lead)
F	1 HCP	LLLT	Northern England	Oncology only (HSCT centre)	Yes (implementation lead)
G	3 HCPs 1 CYP/parent dyad	LLLT	Northern England	Oncology and HSCT	Yes (implementation lead)
H	1 HCP	LED	Midlands	Oncology and HSCT	No (available in PTC)
Peri-Implementation (n = 3 PTCs)					
I	1 HCP	LED	Southern England	Oncology	No (not available in PTC)
J	1 HCP	LED	Northern England	Oncology	Yes (implementation lead)
K	1 HCP	LED	Southern England	Oncology and HSCT	No (not available in PTC)

Abbreviations: CYP = Children and young people; HCPs = Healthcare professionals; HSCT = haematopoietic stem cell transplant; LLLT = low-level laser; LED = light-emitting diode system; PBM = Photobiomodulation; PTC = Principal Treatment Centre.

Compatibility [++/−−] between PBM procedures and existing workflows varied markedly across centres. Delivery by external teams, such as visiting dental staff, often disrupted integration, especially when PBM was used reactively rather than preventively. As a non-pharmaceutical intervention, PBM's alignment with medication and prescribing systems was inconsistent; where it was formally embedded within prescribing pathways, accountability and treatment consistency improved.

4.2 | Individuals

A wide range of *Individual Roles* were identified within the dataset, highlighting the need for a whole team approach to implementation. The *opportunity* [++] and *motivation* [++] of *implementation leads* were key, with dedicated time required alongside persistence to drive the service forward. *Implementation leads* frequently served as 'Champions' within the *Implementation Process* [++].

The *need* [++] of CYP as *innovation recipients* strongly motivated adoption, as PBM was widely perceived to enhance comfort and quality of life. However, delivery relied on the *opportunity* [++/−−] of *innovation deliverers*. Ward-based staff were considered best placed to provide treatment, but their availability and training varied substantially across centres, influencing consistency and reach of implementation.

5 | Theme 2. 'Why Not Try It?' – The Perception of PBM as a Simple, Proactive, and Rewarding Treatment

Influential determinants in this theme primarily related to *Innovation Characteristics* and the *Characteristics of Individuals* involved in delivery and implementation. The *Inner Setting* exerted less influence, resulting in fewer differences between PTCs. Data from all participant groups contributed to theme development (Table 3).

5.1 | Innovation Characteristics

PBM had a strong *relative advantage* [++] in its ability to be delivered preventatively, rather than reactively, and both LED and laser systems were highly acceptable to CYP. PBM was perceived to have inherently high *adaptability* [++], with value placed on CYP autonomy and control in adapting treatment protocols based on their symptoms and their wider care.

Treatment delivery was perceived as simple, from both deliverer and recipient perspectives, with limited *complexity* [++]. However, wider operating procedures relating to disinfection and equipment transport increased *complexity* [−], with laser safety procedures presenting additional barriers for low-level laser systems.

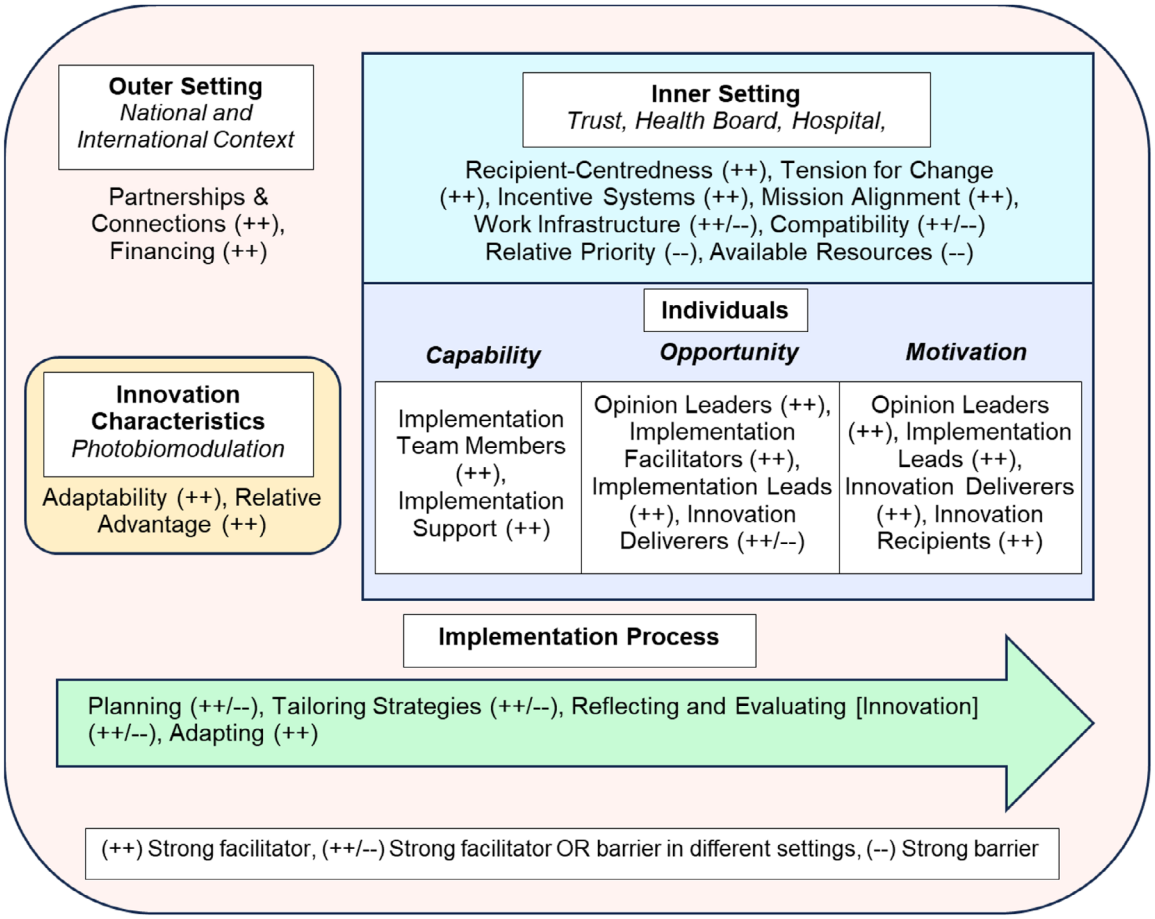

FIGURE 2 | Diagrammatic representation of CFIR domains and substituent constructs with strong influences on PBM implementation.

5.2 | Individuals

A bidirectional relationship was observed between CYP and families as peer *opinion leaders* and HCPs as expert *opinion leaders* in motivating both *innovation deliverers* **and** *innovation recipients*. Both groups expressed strong *motivation* [++] to improve CYP's treatment experiences.

For LED systems, PBM was perceived as a simple skill with low *capability* [++] requirements. This supported training of a wider range of staff groups (including nursing staff and healthcare assistants) and training of families to self-deliver treatment with supervision. Families valued the opportunity to play a proactive role as a strong *motivation* [++], in becoming *innovation deliverers*, and in actively requesting the treatment as *innovation recipients*.

6 | Theme 3. Need for Navigable, Interconnected, Multiprofessional Networks to Support Implementation

Theme 3 was developed exclusively from HCPs' implementation insights. Data were related to facilitators to navigation of implementation processes in the *Outer Setting* and supportive *Individuals* in the local context (Table 4).

6.1 | Outer Setting

Partnerships and connections [++] (through professional societies, networks, and conference dissemination) were important catalysers for implementation. Early adopters benefited primarily from international collaboration, while later adopters drew on emerging national networks and shared UK-based expertise.

6.2 | Inner Setting and Individuals

At the *Inner Setting* level, *work infrastructure* [−−] often hindered navigation of local approval processes. Support from *high-level leaders* [+] familiar with governance pathways facilitated progress, particularly when leaders were accessible to implementation teams.

Effective implementation required diverse expertise across infection prevention and control, medical physics, oncology, and paediatric dentistry. *Implementation team capability* [++] was thus crucial, though limited *opportunity* [−] and coordination challenges within multidisciplinary teams frequently constrained delivery. Visible, ward-aligned *implementation leads* [++] and deliberate *teaming* [+] helped overcome these barriers.

Variation in *work infrastructure* [+/−] (including access to dental teams, departmental proximity, and service size) had modest

TABLE 2 | Summary of Theme 1 constituent qualitative summaries, relevant CFIR constructs, and representative data.

Theme 1. Framing PBM as essential within routine care in busy cancer services		
CFIR domain	**Qualitative summaries (n = 33) – *CFIR construct, [valence]***	**Representative quotes**
(I) Innovation Characteristics	**Less influential** • Balancing costs against service priorities (but overall small ticket item) – *Cost [Neutral]*	'And although there is a cost, it's not ridiculously expensive compared to some other things that we do and deliver here'. *Cost [Neutral]* **HCP4**
(II) Outer Setting	**Highly influential** • Financing of equipment aligns with remit of hospital charitable funding – *Financing [++]* **Less influential** • National focus on supportive care supports implementation – *Local Attitudes [+]* • Scope for funding services through research – *Financing [+]* • Potential for media to increase awareness and demand – *External Pressure (Mass Media) [+]*	'I think most children's oncology units will have an allied charitable thing […] but you know, this is a really nice thing for a charity to provide because it's simple and it's one off, you can demonstrate the benefit […] it's very easy to find a patient who will say how wonderful it is and how grateful they are for it, you know, it's a really good target for charitable funding'. *Financing [++]* **HCP15** 'I think we are better overall generally, across oncology and haematology […] looking at the kind of big picture, the wider, the side effects, obviously that's why there's a whole national group on supportive care for example, because we can see the benefits of, yes, we can't change the chemotherapy drugs but we can help support them through it'. *Local Attitudes [+]* **HCP4**
(III) Inner Setting	**Highly influential** • No other perceived effective treatments for oral mucositis – *Tension for Change [++]* • Integration into care plans, medications, and notes system is needed and highly variable – *Compatibility [++/−−]* • Challenges in prioritisation of perceived optional tasks in otherwise overwhelmed services – *Relative Priority [−−]* • Reduction in workload relating to oral mucositis management – *Incentive System [++]* • Implementation of PBM brings potential health economic and service benefits – *Incentive System [++]* • PBM aligns with mission to deliver patient centred and kinder treatments – *Mission Alignment [++]* • Limited number of trained and available staff affects intervention fidelity– *Available Resources (General – Staffing) [−−]* **Less influential** • Challenges integrating PBM into staff job roles – *Structural Characteristics (Work Infrastructure) [−]* • Need for equitable access, including care closer to home – *Tension for Change [+]* • Differing relative prioritisation between healthcare professionals and families – *Relative Priority [−]* • Families place PBM as high priority during inpatient stay – *Relative Priority [+]* • Implementation of PBM raises the agenda for oral health – *Incentive System [+]* • Access to single set of PBM equipment – *Available Resources (Materials & Equipment) [−]*	'We don't ***have*** any effective treatments for mucositis. We're just constantly rotating around about up to eight different methods to help people ranging from ice chips, ice lollies to steroid cream. So for something that is non-invasive, doesn't involve any pharmacy, if it helps with pain and normal eating then it has to be a huge plus'. *Tension for Change [++]* **HCP16** 'I, as the parent, I would love this to be added to his care plan, meds plan, whatever it is in the hospital, that whoever is looking after [CYP1] on the day […] it's like medication, let's make sure he gets all the medications on the list […]. For example, for the Gelclair [barrier gel], it goes on the meds chart so someone would bring you Gelclair to rinse your mouth but they don't do that with light treatment, because Gelclair they would bring it to you at 8am or 9am whenever, and sometimes you'd wait for his light treatment until 9pm after me nagging about it seven times'. *Compatibility [−−]* **Parent 1** 'I think in the long run, because it is a supportive treatment so to speak and it's not a prescribed thing, I think sometimes it can get forgotten, especially if staff are really short […] You often get parents coming to ask for it, I think the first thing that was said to me today from one of the parents was "I need you today, I need the red lights" and it might have been because yesterday was really busy so they didn't get it'. *Relative Priority [−]* **HCP3** 'And of course, ultimately it saves staff time because you're not dealing with the mucositis itself and the knock-on effects of the mucositis, the inability to eat and drink, struggling to sleep, all of the use of opioids that's necessary. So it's absolutely worth that 5 minutes at the bedside but finding that 5 minutes when you are completely and utterly bare bones, it's tough. Of course it's tough'. *Incentive System [++], Available Resources (General Staffing) [−−]* **Professional11 (Industry)** 'I suppose the most difficult thing was manpower. You know, the machine wasn't difficult, the children weren't difficult when you think what they were going through, and the parents weren't difficult. The main, I think the main issue would be the manpower and having enough people available at appropriate times to treat what was requested' *Available Resources (General Staffing) [−−]* **HCP16**

(Continues)

TABLE 2 | (Continued)

Theme 1. Framing PBM as essential within routine care in busy cancer services		
CFIR domain	**Qualitative summaries (n = 33) – *CFIR construct, [valence]***	**Representative quotes**
(IV) Individuals	**Highly influential** • Dedicated time to establish PBM service – *Implementation Leads (Opportunity) [++]* • Passion, perseverance and dedication in implementing PBM – *Implementation Leads (Motivation) [++]* • Ward-based staff have increased availability for PBM delivery – *Innovation Deliverers (Opportunity) [++]* • Availability of trained staff as the most influential factor on delivery – *Innovation Deliverers (Opportunity) [++/−−]* • PBM is perceived to improve quality-of-life and curative treatment experiences– *Innovation Recipients (Need) [++]* **Less influential** • Championing PBM at senior decision making level – *High-Level Leaders (Motivation) [+]* • Provision of support for staff to attend training – *Mid-Level Leaders (Motivation) [+]* • Establishing PBM in NHS as a motivator for industry – *Implementation Facilitators (Motivation) [+]* • Collective advocacy for PBM – *Implementation Team Members (Motivation) [+]* • Need for healthcare professionals to support self-delivery by patients and families – *Innovation Deliverers (Capability) [−]* • Benefits of improved patient outcomes for families and services – *Innovation Deliverers (Motivation) [+]* • Challenges in co-ordinating PBM against other treatments in inpatient schedule – *Innovation Recipients (Opportunity) [−]*	'I don't think it's a controversial, complex, difficult service to introduce, you just need someone who's prepared to sell it to everyone, and keep selling it, because you've got to keep selling it. It's not just about having the pens [lasers]. I mean if the service is going to work, you have to have the pen [laser] and then get people using it […] and I don't think this service is now dependent on [Implementation Lead]'s continuing presence, but this is a self-sustaining thing, which is because of all the work she's done'. *Implementation Leads (Motivation) [++]* **HCP15** 'The biggest change would be bringing on the Advanced Nurse Practitioners (ANP), and that's been a big evolution […] there are probably more patients receiving laser therapy now from one ANP being involved than all the laser that we [the dental team] did before […] it's not relying on somebody picking up the phone, trying to get hold of me, getting somebody physically on the ward. So the hours that they do, the fact they're physically on the wards and they know the patients'. *Innovation Deliverers (Opportunity) [++]* **HCP1** 'So it was a win-win from the start for me. It saved an admission, it saved his line being accessed when it didn't need to be and it just […] he likes to run around, when he was having his sore mouth he was just in his little corner and he didn't move an inch, he didn't eat, he didn't do anything. So after laser he was back to himself again, and so to me, it helps me get [CYP4] back'. *Innovation Recipients (Need) [++]* **Parent 4** 'But it works and it's really simple, it's relatively cheap and we have seen a ***significant*** reduction in patients needing admission for management of oral mucositis, you know a reduction in the amount of PCAs [Patient Controlled Analgesia] we're using, and kids like it, kids actively come and have it, they believe it, and therefore you know, it's a good thing'. *Innovation Recipient (Need) [++]* **HCP15**
(V) Implementation Process	**Highly influential** • Local champions as a critical implementation strategy – *Tailoring Strategies [++]* **Less influential** • Defining and assessing need and balancing demand with service capacity – *Assessing Needs (Innovation Recipients) [+/−]* • Making PBM visible and raising awareness with healthcare professionals and families – *Engaging (Innovation Deliverers) [+]*	'So I think getting it out there, getting all the stakeholders involved with it and having some champions, which I would happily be, but having a champion of it to say this is really, really good'. *Tailoring Strategies [++]* **HCP14**

TABLE 3 | Summary of Theme 2 constituent qualitative summaries, relevant CFIR constructs, and representative data.

Theme 2. 'Why not try it?' – The perception of PBM as a simple, proactive, and rewarding treatment		
CFIR domain	**Qualitative Summaries ($n = 32$) – *CFIR construct, [valence]***	**Representative Quotes**
(I) Innovation Characteristics	**Highly influential** • Value of autonomy, control, and choices with treatment delivery – *Adaptability [++]* • Value of a preventative option, rather than managing side effects – *Relative Advantage [++]* • PBM is a highly acceptable treatment – *Relative Advantage [++]* • PBM is a simple procedure in itself – *Complexity [++]* • Perceived to be more effective than topical treatments – *Relative Advantage [++]* **Less influential** • Perceptions of PBM as an experimental treatment by families – *Evidence Base [+]* • Family acceptance of a lower evidence base for 'non-pharmaceutical' therapies – *Evidence Base [+]* • Use as an adjunct to existing oral care – *Relative Advantage [+]* • Perception of laser and LED systems depends on previous PBM experience – *Relative Advantage* [+/−] • Wider operating procedures around delivery increase complexity, especially for laser systems – *Complexity [−]* • Connotations of lasers and the influence of how these are introduced – *Design [+/−]* • Assembly, size, and weight of LED system – *Design [−]* • Discomfort and embarrassment with intra-oral LED device for children and young people – *Design [−]*	'I think we just wanted to stop anything, we felt like we had so little control over anything, that anything we could control to make things better we wanted to grab onto and I think we both felt like we didn't have any real control over life and I think that's in some ways why the light therapy was so good, especially when you've got to the point of being able to do it by yourself, you felt like you had the control over it and even now she loves it if somebody leaves the light therapy machine out'. **Parent 2** 'I would far rather do it myself [. . .] than someone's shining a light at me'. **CYP2** *Adaptability [++]* 'So knowing that there was something quick and painless that could be done without putting him through, you know, pinning him down to drop eye drops or making him take this tiny cup of clearly awful whatever the mouthwashy gel [. . .] some sort of sachet as well maybe or there was something that dissolved. There was maybe two options for the sore mouth and whenever that was mentioned we were shut down by him [CYP3] very quickly. And it's like, "Right, well, if we're not going to do the eye drops, the mouth gel, the mouthwash, can we do this [PBM] instead?" [. . .] It felt like we were still doing something to help the mouth without putting him through extra trauma when there's already 50 other things that he was trying to process at the time'. **Parent3** *Relative Advantage [++]* 'I found the device itself really simple to use, it was pretty much kind of foolproof so it was pretty simple and a lot of our patients really quite seemed to enjoy it as well [. . .] I think because there's only so many buttons you can press I guess, if that makes sense. So you kind of have to turn the switch, you press the button and it does it itself really. It's nice to know that it's sort of all safely calculated and things for you so you don't have to be sort of like prescribing particular doses to patients and things like that'. **HCP19** *Complexity [++]*
(III) Inner Setting	**Highly influential** • Enthusiasm from healthcare professionals to implement treatments that make children's lives better – *Culture (Recipient-Centredness) [++]* **Less influential** • PBM becomes a lower priority when CYP experience other debilitating treatment side effects – *Relative Priority [−]*	'I mean, as you know, when you're treating a child and you see children in such significant pain, and you see somebody in another service, be it another country, producing results which have been of significant benefit to their children. You think, "Well, why aren't we at least doing it with ours?", I think that was the main driver'. **HCP16** *Culture (Recipient-Centredness) [++]* 'But it's keeping people out of hospital and that's the major aim, you know, of children's hospitals, is care closer to home isn't it. And making life easier and better for kids who are going through a difficult time. So I think it aligns pretty nicely really'. **HCP15** *Culture (Recipient-Centredness) [++]*

(Continues)

TABLE 3 | (Continued)

Theme 2. 'Why not try it?' – The perception of PBM as a simple, proactive, and rewarding treatment		
CFIR domain	**Qualitative Summaries ($n = 32$) – *CFIR construct, [valence]***	**Representative Quotes**
(IV) Individuals	**Highly influential** • Experience of positive patient outcomes as a motivator for all groups – *Opinion Leaders (Motivation) [++]* • Parents' role as advocates for their child's care – *Opinion Leaders (Motivation) [++]* • Bidirectional role of families as peer leaders and healthcare professionals as expert leaders in motivating innovation deliverers **and** recipients – *Opinion Leaders (Opportunity) [++]* • Knowledge and skills to deliver PBM are simple and teachable to all staff groups and families – *Innovation Deliverers (Capability) [++]* • Positive attitudes and enthusiasm from healthcare professionals influences treatment delivery – *Innovation Deliverers (Motivation) [++]* • Parental desire to play an active role in cancer care – *Innovation Deliverers (Motivation) [++]* • Enthusiasm from families, who often request PBM – *Innovation Recipients (Motivation) [++]* • A proactive, positive, helpful treatment that families can play an active role in receiving – *Innovation Recipients (Motivation) [++]* **Less influential** • Knowledgeable healthcare professionals as a gateway to introducing PBM – *Opinion Leaders (Capability) [+]* • Positive patient outcomes as a motivator for implementation facilitators – *Implementation Facilitators (Motivation) [+]* • Job satisfaction of autonomous service delivery with immediate positive impact for families – *Innovation Deliverers (Need) [+]* • Wider 'soft' skills in management of CYP are needed – *Innovation Deliverers (Capability) [+]* • Children and young people have generally high self-efficacy in relation to PBM – *Innovation Recipients (Capability) [+]* • Difficult to understand mechanism of PBM – *Innovation Recipients (Capability) [−]* • Families feel privileged to receive PBM due to its low availability – *Innovation Recipients (Opportunity) [+]* • Perception of PBM carrying low opportunity cost for inpatients – *Innovation Recipients (Opportunity) [+]* • Motivation of recipients is influenced by previous mucositis and PBM experience – *Innovation Recipients (Motivation) [+/−]*	'I think it's just the drive to do it. Everyone's very enthusiastic. We can see a benefit. I think as our patients are speaking out to the staff members and saying "Actually, that really helped and I really liked it and I really want the laser", then that motivates everybody to work together to make it happen'. **HCP18** *Opinion Leaders (Motivation) [++]* 'I think we were overly keen on it, so I would ask every day and probably there were days where I would literally go to the nursing station seven times or eight times to say "Please could he have light treatment", just because I believed it was so important'. **Parent 1** *Opinion Leaders (Motivation) [++]* 'It just seems like this simple thing, probably if someone had shown me "This is what you do, help yourself to the machine" I could totally do it myself. It just seemed straightforward enough, easy enough'. **Parent 1** *Innovation Deliverers (Capability) [++]* 'So how important would you say that this treatment was available in other children's cancer centres [. . .] from 0 to 100?'. **Interviewer** 'I would say 100. I think it was . . . . Even if it didn't, you know, even if it hadn't done any good - and it did - but even if it hadn't, it was something proactive, positive, and useful that we felt we could be doing at a time when there was nothing else that I felt I was doing that was productive, positive, and useful'. **Parent 2** *Innovation Recipients (Motivation) [++]* 'Did you feel like you had an understanding on kind of how it worked?'. **Interviewer** '(Laughter) Other than this light, magical light, was, I don't know. Does it promote healing? I don't, I still don't think I actually know. Promote healing I guess, or then it's used in the preventative way. Yeah, I think I'm answering your question there that I still don't quite understand. But it was something I was more than happy to ask for on the off chance that I thought it was helping'. **Parent 3** *Innovation Recipients (Capability) [−]*

TABLE 4 | Summary of Theme 3 constituent qualitative summaries, relevant CFIR constructs, and representative data.

Theme 3. Need for navigable, interconnected, multiprofessional networks to support implementation		
CFIR domain	**Qualitative summaries ($n = 26$) – *CFIR construct, [valence]***	**Representative quotes**
(I) Innovation Characteristics	**Less influential** • Relationship with equipment manufacturer – *Innovation Source [+]*	
(II) Outer Setting	**Highly influential** • Support from external networking, professional societies, and conferences facilitates adoption – *Partnerships & Connections [++]* • 'Not re-inventing the wheel' – learning from other units and sharing of resources supports implementation for later adopters – *Partnerships & Connections [++]* **Less influential** • Influence of COVID-19 pandemic on infection prevention and control, and service delivery – *Critical Incidents [−]* • 'We need to be a part of this' – increased market pressure for later adopters – *External Pressure (Market Pressure) [+]* • Influence of international accreditation as a Centre of Supportive Care Excellence – *External Pressure (Performance Pressure) [+]*	'I guess like all these things, it's sort of networking and working together and I guess sharing experiences. Every, I mean the NHS, there's this need to reinvent the wheel in every single hospital, it's so frustrating [. . .] But I think having the support from other units to say, "Yes, it is, it's deliverable, it is safe, it is effective" and you know, sharing that evidence you know, that you have with other hospitals if they are having problems in getting it implemented would definitely help [. . .] but I think it's through the CCLG (Children and Young People's Cancer Assocation) through mutual working, I think it's really important to share experiences'. **HCP6** *Partnerships & Connections [++]* 'You know, the people (staff) have been to talks at CCLG (Children and Young People's Cancer Association conference) and other forums where they've heard about PBM and sort of come back to [the cancer centre] and said "Right, you know, we should be doing this, how can we do it?". So that's what I meant about sort of momentum, it's sort of growing slowly, but we haven't, yeah, haven't quite got there yet'. **HCP9** *External Pressure (Market Pressure) [+]*
(III) Inner Setting	**Highly influential** • Lack of clarity in organisational structure and navigation of implementing new procedures – *Structural Characteristics (Work Infrastructure) [−−]* **Less influential** • Proximity of departments in multidisciplinary collaborations – *Structural Characteristics (Physical Infrastructure) [+/−]* • Size of unit influences implementation fidelity – *Structural Characteristics (Work Infrastructure) [+/−]* • Variation in access to dental teams – *Structural Characteristics (Work Infrastructure) [+/−]* • Capacity to integrate dentists into ward setting and oncology team – *Relational Connections [+]* • Established departmental meetings – *Communication [+]* • Exclusion of nursing staff from departmental meetings limits information sharing – *Communication [−]* • Teaching culture facilitates implementation and practice sharing – *Culture (Learning-Centredness) [+]* • Established teaching structures facilitate training and implementation – *Access to Knowledge & Information [+]*	'It was a nightmare (to implement). [. . .] Because I'd suddenly think "Oh I've got so close now to getting it" and somebody else would say "Well have you gone to this committee?" and I'd think "Well no actually I don't" [. . .] I was very much sort of in the dark about where to go, who to go to, who it needed to be approved by and then suddenly I would get an email and say "Oh you have to get this approved by the medical director" and you know, and you'd go off to try and find them and you'd have to book an appointment, so there were so many layers of you know, things to get through, that it could be streamlined better'. **HCP5** *Structural Characteristics (Work Infrastructure) [−−]* 'So it's very difficult to say. I've struggled with a blueprint for "this is who you see, this is what you say". It just doesn't work like that. You've got to navigate your way through each individual Trust [. . .] From my perspective, when I'm working my way through these Trusts, there's no map to follow. You do have to find out what's happening in that individual Trust'. **Professional 11 (Industry)** *(Work Infrastructure) [−−]*

(Continues)

TABLE 4 | (Continued)

Theme 3. Need for navigable, interconnected, multiprofessional networks to support implementation		
CFIR domain	**Qualitative summaries ($n = 26$) – *CFIR construct, [valence]***	**Representative quotes**
(IV) Individuals	**Highly influential** • Well-known and visible Implementation Leads with a clinical role aligned with the service – *Implementation Leads (Opportunity) [++]* • Provision of multidisciplinary expertise to support adaptation to setting – *Implementation Team Members (Capability) [++]* **Less influential** • Knowledge of inner context implementation procedures to support Implementation Lead – *High-Level Leaders (Capability) [+]* • Variable availability of High-Level Leaders influences implementation – *High-Level Leaders (Opportunity) [+/−]* • 'Buy in' from Mid-Level Leaders increases belief in PBM with other staff groups – *Mid-Level Leaders (Opportunity) [+]* • Availability of technical expertise – *Implementation Facilitators (Opportunity) [+]* • Dental teams benefit from involvement and integration into hospital team – *Implementation Team Members (Need) [+]* • Availability and coordination of team members from different clinical roles – *Implementation Team Members (Opportunity) [+]* • Availability of Implementation Support for liaison with Implementation Leads – *Other Implementation Support (Opportunity) [+]*	'It doesn't have to be a dentist I don't think, you know, yeah, palliative care could do it, could pick it up you know, it's well up their street, acute pain, […] CNS (Clinical Nurse Specialist) who was enthusiastic, you know, the lead leukaemia nurse or lead oncology nurse. Anyone who is in regular contact with patients and enthusiastic about it could introduce the service. It's just happened to be [Paediatric Dentist] here'. **HCP15** *Implementation Leads (Opportunity) [++]* 'My role in it very early on was to find the patients, because what they [the dental team] needed was somebody with the experience of oncology patients, with the experience of chemotherapy protocols and I don't think it would have worked as well if they didn't have somebody with that level of knowledge and experience. So the dentist needed somebody with that oncology head on them, not only to highlight which patients need it but also, what's huge with all of this and what takes a lot of time, is the coordination of these patients on their cancer journey if you like - having chemo, the side effects of chemo, when they're in for clinic - and you need someone with an oncology head on to help coordinate that otherwise I don't think it would work'. **HCP18** *Implementation Team Members (Capability) [++]*
(V) Implementation Process	**Less influential** • Multidisciplinary collaborations of stakeholders and healthcare professionals in successful implementation – *Teaming [+]* • Implementing across multiple services to increase impact – *Teaming [+]*	'One thing that I would share? I mean it comes down to multidisciplinary team working doesn't it? I think what drove it here is the close relationship we have with [Paediatric Dentistry Consultant] and colleagues and I think that's what was instrumental in driving it forward and making it successful. […] So multidisciplinary working is just key isn't it, I mean not one professional can do this on their own, you have to have a team of people that have different expertise and it is essential that that team works together for the benefit of patients and that's you know, that's the nutshell isn't it I think'. **HCP6** *Teaming [+]*

effects overall. Established teaching sessions and departmental meetings improved *access to knowledge and information* [+] and *communication* [+] but often excluded nursing staff, a core group of *implementation team members*.

7 | Theme 4. Balancing Individualisation of PBM Services With the Need for Standardisation and Guidance

Critical determinants in this theme related to the *Innovation Characteristics* and *Implementation Process* domains (Table 5).

7.1 | Innovation Characteristics

The strong *adaptability* [++] of PBM and the flexibility of its delivery supported integration into paediatric cancer and transplant care. This adaptability extended to scheduling, location, and staffing (particularly with LED systems) and to the tailoring of treatment protocols that maintained consistency within local workflows. However, adaptability also introduced complexity; the absence of a single agreed protocol, especially for laser systems requiring energy dosing, increased *complexity* [−] and reflected the limited *evidence base* [−] arising from heterogeneous PBM studies. While international *policies* [+] endorsed PBM implementation, participants emphasised the need for clear, nationally relevant guidance to support standardisation.

7.2 | Implementation Processes

Implementation strategies were influential but varied widely in design and effectiveness. More recent adopters tended to use structured, premeditated approaches, whereas early adopters developed services in a more iterative, "ad hoc" manner. Patient pathways for PBM differed across centres, requiring *adapting* [++/−−] to local patient populations, referral routes, documentation systems, and medical physics requirements. When these factors were addressed through *planning* [++/−−], implementation fidelity was maintained, although no single pathway proved superior.

Structured *planning* [++/−−] and clear delegation of implementation stages facilitated adoption. Participants expressed a strong desire for an "implementation roadmap" – a practical guide based on UK and Irish experiences – that could be applied flexibly across contexts as a *tailored strategy* [++]. Demonstrating service benefits remained challenging due to patient heterogeneity and limited outcome data. Later adopters were more likely to embed *reflecting and evaluating* [++/−−] within standard care and, where evaluation processes were well integrated, they strengthened local service development and supported wider dissemination.

8 | Theme 5: Increasing Implementation of LED Systems, With Reduced Barriers, Over Time

Although this theme was narratively important, it included fewer strong determinants. Influential data primarily related to *Innovation Characteristics* and the *Inner Setting* (Table 6).

8.1 | Innovation Characteristics

Lower *adaptability* [−−] of low-level laser systems compared with LED systems created notable implementation barriers. Laser safety protocols constrained treatment locations, required specialist training, and prevented patient self-delivery, limiting flexibility. In contrast, LED systems removed these constraints, providing a clear *relative advantage* [++] that facilitated adoption in later-implementing centres.

A growing *evidence base* [+] for LED systems further supports their use, though direct comparative trials remain limited. Clinicians relied on experiential or observational evidence, and the term PBM was applied broadly in clinical guidance [+]. For many, the practical benefits of LED systems – simplicity, safety, and portability – outweighed differences in formal evidence strength. These pragmatic advantages reduced contextual barriers otherwise identified in *assessing context* [−] for laser-based delivery

8.2 | Inner Setting

Physical infrastructure [+/−] within PTCs also shaped system choice. Laser systems required enclosed or modified treatment rooms, creating difficulties in open or glass-fronted bays and in wards lacking laser-safe spaces. This dependency on environment and equipment constrained *available resources (space)* [−], particularly when treatment rooms served multiple clinical purposes. LED systems, being portable and room-safe, were more compatible with routine inpatient care and thus more readily integrated into existing workflows.

8.3 | Implementation Strategies

Forty-nine barriers, 12 with strong influence, were mapped against 21 distinct ERIC strategies (Supplementary Table S1). Two barriers relating to *Innovation Characteristics* could not be mapped to implementation strategies, as they represented fixed PBM features.

Assessment of local context for barriers and facilitators (n = 8), development of a formal implementation blueprint (n = 4), and promotion of adaptability (n = 5) were the most frequently mapped strategies. This highlighted the need for structure and guidance, whilst adapting strategies, through planning and assessment of context in implementation approaches.

9 | Discussion

This study identified the principal barriers and enablers influencing implementation of PBM within paediatric oncology and haematology in the United Kingdom and Ireland. Applying implementation science theory enabled systematic analysis of these determinants and informed development of an adaptable,

TABLE 5 | Summary of Theme 4 constituent qualitative summaries, relevant CFIR constructs, and representative data.

Theme 4. Balancing individualisation of PBM services with the need for standardisation and guidance		
CFIR domain	**Qualitative summaries ($n = 26$) – *CFIR construct, [valence]***	**Representative quotes**
(I) Innovation Characteristics	**Highly influential** • Flexibility of delivery supports adoption in cancer and transplant context – *Adaptability [++]* • Adaptability of protocol and optionality of intra-oral treatment – *Adaptability [++]* **Less influential** • Lack of evidence for a specific treatment protocol – *Evidence Base [−]* • Potential application of PBM for other indications in the local context – *Adaptability [+]* • Limitation of inability to treat gastrointestinal mucositis – *Adaptability [−]* • Initial trial period offered by leading manufacturer – *Trialability [+]* • Lack of defined and accepted protocols increases complexity, especially for laser systems – *Complexity [−]*	'But another thing, an important thing as well, when he was so poorly the first time round and was admitted for high dose methotrexate, he couldn't get out of bed. So, asking him to go another room would be a challenge, he simply probably wouldn't go. For the first week he didn't get out of bed, he even struggled to go to the toilet at some points […] So, the fact that they can bring the machine to your bed, I think it just makes it easier, more accessible I guess […] If you don't have the energy to hold the light… and I think there were a couple of days where [CYP1] said "I don't even want to hold the light" and it was someone else actually holding the light for you'. **Parent 1** *Adaptability [++]* 'So there's decades worth of clinical evidence, and the clinical evidence consistently says that PBM works, photobiomodulation is an extremely effective intervention. What it [the literature] doesn't do and what it has really struggled to do is establish – but at what dose? What's the treatment protocol? What's the frequency of treatment? Those kind of really practical questions – it's really difficult to find consensus across the evidence […] [and so] you will get different people discussing different protocols'. **Professional 11 - Industry** *Evidence Base [−]*
(II) Outer Setting	**Less influential** • International mucositis guidance supports implementation but specific national PBM guidance is desired – *Policies & Laws [+]*	'So I knew it was NICE (National Institute of Health and Care Excellence) approved, and then MASCC which is the Multinational Association for Supportive Care in Cancer approved it and recommended it for their patients but we don't tend to use a lot of their guidelines within paediatrics yet or, maybe we never will. So I guess it wasn't as nationally approved as we would like to begin with, but I think going forward then it certainly will be'. **HCP4** *Policies & Laws [+]*
(III) Inner Setting	**Less influential** • Challenges establishing ongoing service costs – *Available Resources (Funding) [−]* • Difficulty establishing bespoke local training without guidance – *Access to Knowledge & Information [−]*	'So ongoing costs will be service charges. So it would only cover, our Trust funding, would only cover the cost of the equipment [. .] and then it's going to be the ongoing costs of servicing and then the [disposable plastic] sleeves. […] You can roughly gauge it but it's quite hard to, to give those figures when you're not 100% sure of how many [patients] might be coming through and when people want those exact figures I found that quite hard'. **HCP12** *Available Resources (Funding) [−]*

(Continues)

TABLE 5 | (Continued)

Theme 4. Balancing individualisation of PBM services with the need for standardisation and guidance		
CFIR domain	**Qualitative summaries ($n = 26$) – *CFIR construct, [valence]***	**Representative quotes**
(IV) Individuals	**Highly influential** • Provision of external experience and knowledge of PBM and its implementation – *Implementation Facilitators (Capability)* [++] • Technical expertise and support from medical physics and infection prevention and control – *Other Implementation Support (Capability) [++]* • Lack of dedicated role decreases accountability and consistency of delivery – *Innovation Deliverers (Opportunity) [−−]* **Less influential** • Implementation Leads need sufficient knowledge and skills in PBM to lead the Implementation Team – *Implementation Leads (Capability) [+]* • Protection of patients from laser safety and cross-infection perspective whilst wanting to improve patient outcomes – *Other Implementation Support (Motivation) [+]*	'I think definitely knowing who's done it already and then knowing key people. I think key people have definitely helped me, knowing of people that wouldn't mind obviously sharing their experiences and showing their information of how maybe they've set it up and maybe some key idea of where you could go and how to start off. Because sometimes it's like, I haven't even an idea of how to get on this train, let alone where to go with it'. **HCP12** *Implementation Facilitators (Capability)* [++] 'So then the laser protection managers, the people who manage that department came and we looked together at the whole department, where we were going to do it [low-level laser PBM], the rooms, what we needed, we drafted local rules, risk assessments. We did everything, both of us did it together, and it was just really about making sure that everywhere was laser safe, not only for the children but everyone else'. **HCP5** *Other Implementation Support (Capability) [++]* 'So I think that certain people are more on it [PBM delivery] than others and so if they are on shift they [patients] are more likely to have it consistently. For example, me, just because I'm invested in it, I will always check, but I think that it's part of my role. Whereas, you know, some other people might just not think about it or whatever. So I would say that there probably is some gaps there into how consistently someone gets it'. **HCP7** *Innovation Deliverers (Opportunity) [−−]*

(Continues)

TABLE 5 | (Continued)

Theme 4. Balancing individualisation of PBM services with the need for standardisation and guidance		
CFIR domain	**Qualitative summaries ($n = 26$) – *CFIR construct, [valence]***	**Representative quotes**
(V) Implementation Process	**Highly influential** • Defining roles, pathways, and protocols for services – *Planning [++/−−]* • Outlining and designating implementation steps and processes – *Planning [++/−−]* • Desire for an implementation 'roadmap' with supporting documents – *Tailoring Strategies [++/−−]* • Incorporation of evaluation data to support service development – *Reflecting and Evaluating (Innovation) [++/−−]* • Patient pathways as the most variable and adaptable feature to support compatibility – *Adapting [++]* **Less influential** • Lack of defined PBM competency for training and job plans – *Assessing Needs (Innovation Deliverers) [−]* • Variation in defining and determining target population – *Assessing Needs (Innovation Recipients) [−]* • Assessment of environment and processes for Infection Prevention and Control – *Assessing Context [−]* • Engagement with families to shape and improve services – *Engaging (Innovation Recipients) [+/−]* • Variable use of phased implementation to fine-tune services – *Doing [+/−]* • Incorporating service evaluation into implementation – *Reflecting and Evaluating (Implementation) [+/−]*	'So the service developed in a very ad hoc way and I have so many regrets I suppose about this, and we just did it on request and then we found we [dental team] were getting the request at the beginning of the day and then another request for another patient at the end of the day and that was becoming difficult.' **HCP2** *Planning [−−]* 'Our adaptation would be the pathway, I need to look at that. It's been interesting to think about making sure the pathway is kept very slick and I don't want any kind of hiccups on that from a referral point of view. And not just "Oh, can you do this child? Can you do this child?" It needs to be a bit slicker than just word of mouth. It needs to be quite a slick referral pathway actually, I think that's probably the biggest thing for us right now'. **HCP12** *Planning [++], Adapting [++]* 'I guess when we're, you know, a bit further down the line, having a sort of idiots' guide to how to implement PBM in your centre, a kind of, you know, these are the common pitfalls and you know, challenges that other centres have overcome. This is how we've done it. […] So almost having a kind of template for that, that could be sort of amended for local implementation, I think would be hugely helpful because I think otherwise everyone's reinventing the wheel every time […] you can cut and paste this, or amend it, and here's the evidence and here's the costs'. **HCP9** *Tailoring Strategies [++]*

TABLE 6 | Summary of Theme 5 constituent qualitative summaries, relevant CFIR constructs, and representative data.

Theme 5. Increasing implementation of LED systems, with reduced barriers, over time.		
CFIR domain	**Qualitative summaries ($n = 11$) – *CFIR construct, [valence]***	**Representative Quotes**
(I) Innovation Characteristics	**Highly influential** • Decreased adaptability of low-level laser systems – *Adaptability [−−]* • Perceptions of LED systems as being easier to implement – *Relative Advantage [++]* **Less influential** • Growth of evidence base for PBM over time – *Evidence Base [+]* • Large weight placed on patient-reported, anecdotal, and observed benefits – *Evidence Base [+]* • Balancing evidence base for low-level laser systems against practicalities for LED PBM – *Evidence Base [+/−]*	'I suppose the other thing that's challenging is if they're unwell at that time, if they've got bad mucositis at that time, what else is clinically going on with them. […] Sometimes they just won't want to get out of bed and it's [low-level laser PBM] not a device that we can take to them, they have to come to a [laser safe] room to have it, so I think clinically how they are is huge as well'. **HCP18** *Adaptability [−−]* 'I think the ability to have the built environment allowing laser therapy in every individual patient room is a significant improvement. […] But having said that, the use of non-laser [LED] PBM gets round that. So I would say it's a boon for us to be able to use the laser in that environment, but for a unit that hasn't used it before, LED its probably the way that I would go and I think I would suggest it'. **HCP1** *Adaptability [−−]* 'However, I'm mindful that if I was starting this whole thing from afresh today, the likelihood is I would be far more inclined to go for non-laser LED because the evidence to date seems to be supporting a similar efficacy, but the difficulty I would say in moving to that directly now, is that the best evidence and the longer, wider evidence with NICE (National Institute for Health and Care Excellence) support, with their guidance it still refers to [laser], and there's not been an update of that to reflect to the same level, non-laser, and therefore you've got, what you would consider gold standards [laser] and then you would be changing to a non-gold standard [LED] and it's not that you couldn't justify it [LED] because there's a whole load of reasons why it would be easier than non laser'. **HCP1** *Evidence Base [+/−]* 'I think it's just getting the right one [PBM system] and I think it was also the governance around a low level laser was a swaying factor as well, of trying to get that through the Trust and having everything for that, with the signage going through external departments as well'. **HCP12** *Relative Advantage [++]*
(III) Inner Setting	**Less influential** • Layout of bed spaces influences laser safety in delivery of low-level laser systems – *Structural Characteristics (Physical Infrastructure) [+/−]* • Influence of innovation-centred and risk-averse cultures – *Culture (General) [+/−]* • Increased space requirements for low-level laser systems – *Available Resources (Space) [−]* • Increased resource need for laser safety paraphernalia – *Available Resources (Materials & Equipment) [−]*	'At the time, it had to be administered in a room with no windows, with a lockable door, various ventilations et cetera, et cetera. And in our old hospital, which was a very old Victorian building in [city centre] we had kind of a lack of space. So I do remember it when we used to have to lock our treatment room, so it did actually block a lot of care in the time administering the actual procedure, which is relatively quick but setting it all up, putting in the safety precautions in terms of the safety posters and things for the doors, put the goggle on et cetera et cetera'. **HCP10** *Available Resources (Space) [−]*

(Continues)

TABLE 6 | (Continued)

Theme 5. Increasing implementation of LED systems, with reduced barriers, over time.		
CFIR domain	**Qualitative summaries ($n = 11$) – *CFIR construct, [valence]***	**Representative Quotes**
(IV) Individuals	**Less influential** • Perception that low-level laser systems require increased knowledge and skills restricts the scope of staffing – *Innovation Deliverers (Capability) [−]*	'It [low-level laser PBM] comes with a level of clinical decision making and I suppose maybe that's because of the device that we have, we have to make a decision on what grade of mucositis they've got. We have to then decide what strengths of laser to give so I think to ask a junior member of staff to make those clinical decisions is a bit unfair and it would be very challenging for them. I know in other centres they've got the devices [LED] that is one setting, you press a button and off you go, but I think the device that we've got possibly adds a level of complexity to that so you need a more advanced level of clinical decision making with it, if that makes sense'. **HCP18** *Innovation Deliverers (Capability) [−]*
(V) Implementation Process	**Less influential** • Assessment of environment for laser safety and infection prevention and control – *Assessing Context [−]*	'So any room that our laser has to be delivered in has to be signed off by medical physics, just because there is a very, it's a very, it's theoretical, but it's a risk that it might bounce off shiny surfaces. So they have to come round and just make sure that the door can lock, that the blinds down, that there's not too many shiny surfaces and the shiny surfaces that we do have can be covered by something'. **HCP7** *Assessing Context [−]*

evidence-based implementation strategy. This provides the basis for future development of an implementation resource, based on UK and Irish experiences, offering a pathway to address current inequities in access for CYP, and to strengthen delivery of research-informed supportive care.

Inherent features of PBM: *adaptability, relative advantage*, and the strong *tension for change* surrounding management of oral mucositis, were key facilitators and helped combat contextual variation. But the study also revealed heterogeneity between PTCs in infrastructure, staffing, and service organisation, each influencing fidelity of delivery.

Existing professional and organisational networks supported adoption, but a 'one-size-fits-all' model limited scalability. Implementation therefore requires a balance between structured guidance and local adaptation to match local contexts. Increasing use of LED systems may ease implementation compared with low-level lasers, though their greater flexibility could introduce more clinical variability. Clinicians establishing PBM services should consider both the *implementability* of the system type and integration within existing patient pathways.

Implementation science frameworks provide a rigorous lens for analysing complexity and guiding strategy development [24]. Their value is increasingly recognised in oncology; the Lancet European Groundshot Commission, for example, called for sustained investment in implementation research to bridge the gap between evidence and clinical care [25]. But the application of theory-driven approaches in paediatric oncology is limited. Previous studies (primarily in human papillomavirus vaccination and psychosocial screening) [26] and a recent CFIR-based analysis of fertility counselling for young people [27] highlight similar determinants around *compatibility* with local systems and the importance of planning and adaptation. However, these studies were conducted in US settings with distinct financing and incentive structures, and older participants, limiting generalisability to UK paediatric contexts. Our study extends the evidence base by examining determinants of PBM adoption in a publicly funded health system, and by generating transferable insights for other non-pharmacological supportive care interventions. Theoretically, it additionally applies the CFIR 2.0 in this context and demonstrates a methodological approach to mapping Expert Recommendations of Implementing Change to this updated framework.

The patient and family perspective remains under-represented in implementation research, particularly in paediatrics [28]. In this study, children and parents acted as *opinion leaders*, enhancing staff engagement and supporting delivery fidelity. CFIR constructs beyond the immediate treatment experience – for example, outer-setting or process determinants – were less readily captured from family data. Future research should combine family experience and professional implementation insights to foster a more complete understanding of how children's cancer interventions are introduced, normalised, and sustained [29].

Quantitative measures regarding financial and resource capacity were not collected, due to centralised commissioning of paediatric cancer services and an opacity of these data. The present study presents clinicians' qualitative perspectives on the resources and financial support in their settings to support PBM.

Implementation and delivery of PBM, and supportive care more widely, lie outside of mandated care and service standards [30]. This reduces financial incentives and impetus to implement and deliver these treatments, with adoption demonstrated to be professional led and of lower priority compared to curative care. PBM implementation therefore frequently drew on allied charitable funding to support capital costs, with ongoing consumable and service costs absorbed by the individual service. This highlights a gap between patients' supportive care needs and the funding of these services; until delivery of supportive care is mandated within service specifications, supported by appropriate remuneration, its delivery is driven by best-practice guidance and clinical teams' recipient-centred motivations.

A strength of the present study lies in its methodological rigour with participant triangulation, theory-driven analysis, and application of peer debriefing [31]. Consideration was given to the influence of the researchers on data collection and shaping of study findings. A parent–CYP dyad approach was used to elicit differing perspectives and to support CYP participation; this approach has proven successful in our previous research with this population [3, 11]. Sense checking was completed with PPI groups, supporting the interpretation of families' interview data, and within the wider research team. The lead researchers, CH and BP, had led the implementation of PBM locally and were known to many HCP participants in this capacity. This may have influenced participant responses, should they not wish to share challenges with implementing (HCPs) or negative local treatment experiences (families). However, this expertise supported familiarity with the dataset and interpretation of key findings. A reflexivity log was kept by the lead researcher, which supported the challenge of evolving perspectives and influence on the data in discussion with the wider research team [31].

Study findings have directly contributed to the co-design of an implementation resource with HCPs, CYP with PBM experience, and their families. Participatory co-design approaches have been employed to prototype a research-informed implementation package, aimed at professionals at pre-adopting sites, to facilitate adoption of new PBM services that meet the needs of CYP and their families. The next phase of this research is to test this implementation strategy in diverse haematology and oncology contexts, as part of a mixed-methods evaluation.

10 | Conclusion

PBM is an effective, acceptable, and implementable intervention for preventing oral mucositis in paediatric oncology. Its adoption in the United Kingdom and Ireland has been shaped less by clinical uncertainty than by contextual and organisational factors.

Applying implementation theory revealed practical routes to overcome these contextual and organisational barriers through structured planning, local adaptation, and engaging families and professional networks. Embedding such strategies could improve equity of access and inform wider adoption of other evidence-based supportive care interventions in paediatric settings.

Author Contributions

All authors contributed to the manuscript in a significant way. CH, PD, BP, and CT contributed to the conception of the study and the application for grant funding and the ethical approval application. KG-B provided expertise in qualitative methods and implementation science, which shaped study design and analysis. CH and BP completed all interviews. CH completed primary analysis, management of the research, and led the writing of the article. All authors reviewed the completed article. All have reviewed the manuscript prior to submission.

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Ethics Statement

Ethical approval was granted by the NHS Health Research Authority (24/YH/0080), with the University of Leeds as sponsor. Participants age 16 years and over provided consent to participate in the study. Children and young people under the age of 16 years provided assent, with an adult with parental responsibility providing consent to participate.

Conflicts of Interest

No conflicts of interest were identified by any of the authors.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.

Supporting Table 1: Frequency of implementation strategies against identified barriers.