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Identification and appraisal of the outcome measures used to evaluate hypodontia care: A systematic review

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All authors contributed to the design of the review, development of the protocol, data analysis and review of the manuscript. Sophy Barber and Balvinder Khambay were responsible for identifying and selecting the studies. Sophy Barber undertook data extraction, analysis and preparation of the manuscript.

Declarations

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Hypodontia affects the permanent dentition in 4-6% of the population[1,2] with substantial impacts on functional, emotional, social wellbeing and oral health-related quality of life[3,4]. The variation in severity and presentation of hypodontia results in a range of care (i.e. treatment options and configuration of care pathways for service delivery) that is often complex, multi-disciplinary and delivered over a protracted time period. Adopting an evidence-based approach with patient-centred outcomes is important for shared decision-making, to allow individuals to choose care that is consistent with their values. Inconsistency in outcome measures presents challenges for comparing treatment efficacy between studies while outcomes that fail to consider what is important to patients will contribute to a clinician-directed process. The orthodontic community needs to encourage the use of consistent outcomes across all types of research and service evaluation and strive for outcomes that are of most value to patients, clinicians and stakeholders. This will enable shared decision-making, improve satisfaction and adherence to care and direct effective use of health resources.

Our preliminary scoping search of the literature identified four previous reviews relating to specific types of hypodontia or treatments[5-8] but none that examined the outcomes used for evaluating hypodontia care. Despite an abundance of studies evaluating hypodontia care, there appeared to be little consistency in the outcomes chosen to measure effectiveness. This is concordant with a recent systematic review of orthodontic trials with children, which found significant limitations in the choice of research outcomes and a focus on physical changes caused by treatment[9, 10]. The authors highlighted the need to determine important and relevant outcomes from the perspective of all stakeholders, including patients and clinicians.

This study aimed to identify and appraise which outcome measures have been used to evaluate hypodontia care. The objectives were to (1) identify studies that evaluate hypodontia care, where hypodontia care is defined as both treatment methods and service delivery (2) classify the outcomes used in the studies (3) appraise the outcomes in terms of patient relevance and ability to improve clinical care.

MATERIAL AND METHODS

The systematic review was conducted using best-practice principles[11, 12] and with guidance from previous reviews exploring research outcomes[9, 10]. A preliminary

scope of the literature confirmed no reviews were planned or published on this topic. Stakeholder opinion was sought from providers of hypodontia care and people with hypodontia in Leeds Dental Institute during protocol development to maximise the relevance and applicability of this review. The protocol, published on PROSPERO in May 2015[13], was devised with a broader scope from which the identification of hypodontia care outcomes was one component.

The search strategy was deployed across six electronic databases using search terms related to hypodontia and treatment methods, plus four further electronic databases searched using terms for hypodontia only (Table 1). No language restrictions were used. Additional grey literature searching was performed for unpublished or non-academic literature; hand searching of reference lists of relevant publications and reviews, citation searching for relevant papers identified in searches and personal contact via email with the members of two dental specialty societies. Search terms were developed through piloting alternative search concepts based population, intervention and outcome to estimate sensitivity and specificity. Two concepts were used for searching based on MeSH terms and free headings for hypodontia and treatment methods (Supplemental Table 1).

Inclusion and exclusion criteria for study selection were developed by the authors (Table 2). Studies including participants with syndromic hypodontia and cleft lip and palate were excluded due to potential differences in treatment options and care provision. Mixed method study designs were included to ensure comprehensive identification of outcomes relating to care evaluation. Quality improvement methods such as audit and service evaluation, whilst distinct from research, were included as a potential source of information about stakeholder priorities and expected care standards. These records were managed separately during data extraction and synthesis.

Titles identified through the electronic database searches were collected and imported into EndNote X4. Programmed de-duplication was undertaken and checked manually using a sample of studies to ensure the automated process was reliable. References were screened initially by title by one reviewer (SB) with verification of excluded titles by a second reviewer (BK). No errors were identified. Abstracts for all relevant titles were retrieved and evaluated independently by two reviewers (SB and BK). Full text articles were obtained for studies meeting the inclusion criteria or where it was not possible to make a decision based on the

abstract. Potential articles found through grey literature searches were included at this stage. Two reviewers (SB and BK) reviewed the full text articles independently and disagreements were resolved by consensus. Excluded studies were indexed in Microsoft Excel v14.7.4 with a reason for exclusion.

A data extraction form modified from the Cochrane Public Health Group template[14] was used to systematically extract data from each study. Coding was piloted for suitability prior to commencing the review and developed through an iterative process until the form was judged fit for purpose. The following data items were extracted: Author, Date, Design, Setting & Country, Participants, Interventions, Comparator, Outcome, Measurement Tools, Reference for Tool, Follow-up period. Data extraction was completed by one reviewer (SB) and checked for accuracy and consistency by a second reviewer (BK)[15]. Corrections were recorded to check for areas of ambiguity that would indicate internal inconsistency.

Synthesis of the studies was undertaken by using a novel categorisation approach using the perspective of the evaluator in study. Four outcome categories were developed: three subjective outcomes grouped by assessor (patient-reported, clinician-reported and lay-reported) and one objective outcome (clinical indicators). Within each outcome category, themes and subthemes were used to separate the outcomes. For example, the patient-reported outcome category included themes for quality of life, appearance, function and service delivery. Within the appearance theme, the outcomes were further divided into subthemes including dental appearance and smile attractiveness. This coding theme was adopted to emphasise the use of patient-centred outcomes and to aid future work developing outcomes of relevance to patients, clinicians and stakeholders. This differs to the method previously reported in reviews of research outcomes[9, 10] where the outcome domains concerned outcome from treatment in terms of efficacy.

In line with a previously published review exploring research outcomes[9] no synthesis of efficacy data was planned. Consequently a methodological quality appraisal of studies was not undertaken because the use of outcomes might not be reflected by the quality of the studies.

RESULTS

Electronic searches were initially completed on 1st September 2015 and were updated on 19th December 2016. The PRISMA flow diagram demonstrating study selection is shown in Figure 1. A total of 56 research records[16-71] and eight quality improvement records[72-79] were included in the review (Supplemental Tables 2-9). The research reports included one randomised[37] and two non-randomised controlled trials[26, 42] and 53 observational studies[16-25, 27-36, 38-41, 42-71] (Table 3). Research activity in hypodontia has grown with a noticeable increase in publications from 2000 onwards. The majority of studies (43/56 (78%)) originated from Europe. The research teams were from a dental background and based in a University or Hospital institution with a few based in private practice. All studies were published in dental journals. Details of the key characteristics of the studies are summarised in the appendix, grouped by intervention. Studies evaluated a single treatment method[16-56] (n=41), comparison between methods[57-68] (n=12) or evaluation of service delivery[69-71] (n=3). Only three studies evaluated service delivery rather than outcomes from specific treatment methods (Table 4). The eight quality improvement reports were clinical audits undertaken in NHS Hospitals and published between 2002 and 2016. The purpose of the audits was evaluation of service delivery including treatment duration clinical efficiency, treatment planning, record keeping and access to care (Table 5).

Clinical indicators

Clinical indicators were the most popular outcome, used in 49 (88%) research studies (Table 6) and in all the audits for evaluating service delivery. The experimental studies used clinical indicators alone[26, 37] or in conjunction with patient-reported evaluation of appearance[42] to measure the success of treatment. Dental health, treatment longevity and treatment success were measured exclusively with clinical indicators. Variability was found in the choice of measurement tools used (Table 7). For some outcomes, such as technical and biological complications, implant success and subthemes relating to dental health, the precise measurement method varied across the studies due to inconsistency in the definition of the outcome. In comparison, easily defined outcomes, for example treatment survival, were more uniform in the measurement tool used. Interestingly, service delivery was evaluated with clinical indicators in only three studies and none reported involvement of health service researchers or stakeholders.

Patient-reported outcomes

Patient-reported outcomes were reported in 22 (39%) of studies, most commonly alongside clinical indicators (Table 6). No audits reported the use of patient–reported outcomes. Three studies used exclusively patient-reported outcomes[31, 69, 71]. Oral health-related quality of life (OHRQoL) and patient satisfaction and experience were measured in relation to a specific treatment or to hypodontia care as a whole. The Oral Health Impact Profile (OHIP) was the most popular patient-reported measurement tool, used in full or limited to specific domains relating to function and appearance. On the other hand, the questionnaires used to measure patient satisfaction in four studies were each developed for the individual study with little uniformity between the questionnaires. Patient-reported outcomes relating to smile attractiveness[42, 58, 66], dental appearance[62-64], masticatory ability[38, 39, 41] and functional disturbance[23] were used to determine patient perception of success following specific hypodontia treatments. Symptoms of temporomandibular dysfunction (TMD) were used as a marker of harm from treatment[23-25, 65]. No studies indicated patient involvement during development of the outcomes or selection of measurement tools.

Clinician-reported and lay-reported outcomes

Clinician and lay-reported outcomes were limited to outcomes relating to appearance; specifically smile attractiveness and dental appearance. A wide variety of measurement tools were employed for clinician evaluation of appearance, with consistency only seen in studies undertaken by the same research teams.

DISCUSSION

Patient-centred delivery of care and shared decision-making in treatment planning requires provision of information that is useful and relevant to patients, yet this review illustrates inadequacies in the selection of appropriate outcome measures. People with hypodontia and their families are often committing to long courses of complex treatment. To enable effective care delivery patients need to understand likely treatment consequences based on evidence that uses patient-centred outcomes. This review is unique in categorizing the outcome measures that are currently being used to evaluate treatment methods and service delivery in hypodontia. Understanding the characterization of potential outcomes and providing a system for categorization can assist the development of outcomes that satisfy all stakeholders in future studies.

A variety of outcomes were identified from existing research but these predominantly assessed the efficacy of specific treatments. Few studies indicated how the selection of outcomes and subsequent findings was expected to translate into improvements in clinical care. The lack of consistency in outcome measures limits the scope for comparing and combining study findings. Currently the choice of outcomes appears to be largely driven by dental professionals and researchers. No studies reported patient or public involvement in research design and selection of outcomes and few teams included health services research methodologists. This observation has three key implications: 1) the information gained from research may have limited value for patients during decision-making; 2) there will be challenges when attempting to synthesise the evidence-base for translation into practice; 3) the research findings are unlikely to be able to drive improvements in health services.

Clinical indicators were dominant throughout the studies, particularly for evaluating dental health following treatment and success of treatment. While clinical indicators can provide information about the effectiveness of treatment, the findings may have limited relevance for patients if a high level of dental knowledge is required for interpretation. Outcomes relating to quality of life and appearance are likely to be relevant to patients, as both have been shown to be motivators for seeking treatment and a determinant of satisfaction with treatment[69]. It is less clear whether patients consider mastication and TMD a useful measure of function and harm from treatment. A number of potential outcomes that could provide useful patient information for decision-making were absent, such as patient preferences for dental

health, treatment success and further outcomes associated with service delivery. Clinician-reported outcomes were surprisingly scarce, limited to judgements on appearance following treatment. The beliefs, preferences and unconscious biases of treatment providers could potentially influence patient decision-making and evidence about clinician perception would be useful.

Perhaps most surprising is the almost complete absence of outcomes from a service delivery perspective. Health service research outcomes, such as measures of access to care, acceptability of treatment and cost-effectiveness are essential for driving change[80]. Quality improvement studies were included in the review, with the expectation that the reports would indicate some outcomes that are important to service providers. While the audits did provide some additional outcomes, these were limited to clinical indicators for measuring service delivery. Inadequate evidence for evaluating service delivery presents a barrier to improving services and wider health. The prominence of evidence-based dentistry and development clinical guidelines has resulted in an emphasis on randomised controlled trials to measure the efficacy of treatments. This may have contributed to a reduced focus on service evaluation and the scarcity of health service research values in dental research. Present-day outcomes are unlikely to be able to answer important service delivery questions, such as whether a discrepancy exists between different providers of dental treatment, the effect of the dental care system on the health of hypodontia patients and how social factors and organisation structures may impact on care provision. To enable recommendations to be made for improving hypodontia care, a broader approach to selecting research outcomes is required to incorporate information about the organisation, management, finances and delivery of care.

Trends were noted in the study characteristics and outcomes that reflect changes in research philosophy and the paradigm shift towards patient-centred care. Research activity has increased over time with a move towards assessing patient-reported outcomes. Oral health-related quality of life was first used in 2009[41, 66] but has since been used in four further studies[31, 35, 39, 69]. The use of qualitative methods to gain a deeper understanding of patient experience was only recently reported[69, 71] but is likely to continue to gain popularity. Clinical indicators have remained popular over time but there are signs of progress towards using better-defined, standardised measurement methods. Use of a standardised and validated tool is variable across all outcomes, and although some outcomes such as OHRQoL tend to consistently use a widely accepted measurement tool (the OHIP), the tools for other outcomes,

such as appearance, remain inconsistent.

In all studies the construct of the research question and subsequent study design will influence the suitability and selection of outcome measures. Although RCTs are preferable for determining the effectiveness of a treatment, other research questions may demand different study designs[81] for example, surveys using qualitative methods to understand patient experience. In some instances retrospective studies may be the only feasible design, for example determining long-term survival of primary teeth, but outcomes in these studies will be limited by the availability of existing information. Regardless of study design, coherence is needed between the purpose of the research, the underlying theoretical basis and the research design. The suitability of the outcome is intrinsically linked to the setting, participants, intervention, comparator and methods. The location of studies, composition of the research team and healthcare system in which the results will be applied are likely to influence the choice of outcomes. Universities may be more driven by academic interest than practice-based research teams, who will often be motivated by a need for clinical information or incentives for change.

This review is strengthened by the rigorous methodology and originality in subject and approach. The review was conducted following best practice guidelines and the findings will inform future research regarding development of patient-centred evidence for shared decision-making.

CONCLUSIONS

There is a lack of rationale and consistency in the selection of outcome measures used in evaluating hypodontia care. Research outcomes are largely clinician and research-driven with little evidence of their relevance to patients. A notable scarcity of outcomes concerning access to care, quality of care and cost was found. The findings from this review have two potential impacts. Firstly, the inadequacies identified in current outcomes provide vital information for developing consensus regarding the selection of research outcomes to drive improvements in hypodontia care. Secondly, the framework for characterising outcomes using categories relating to the research perspective can aid selection of relevant research outcomes to facilitate shared decision-making across hypodontia care.

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Supplemental Table 1: Search terms grouped into search concepts

Search concept: Hypodontia	
1.	Hypodontia.tw or Anodontia.tw or oligodontia.tw
2.	(Tooth or teeth or dental).tw adj1 (aplasia or agenesis).tw
3.	(Developmental$ or congenital$).tw adj1 (missing or absen$).tw adj1 (tooth or teeth or dentition).tw
4.	Exp Anodontia/
5.	1 or 2 or 3 or 4
Search concept: Treatment	
6.	Treatment$.tw or manage$.tw or method$.tw or technique$.tw or care.tw
7.	Exp dentistry/ or Exp comprehensive dental care/
8.	Dentistry.tw or dental care.tw
9.	Orthodonti$.tw or brace$.tw
10.	Orthodontic closure.tw or space closure.tw or orthodontic opening.tw or space opening.tw
11.	Restorat$.tw or (restorat$ adj1 dent$).tw
12.	(Prosthe$ or bridge$ or denture$ or crown$).tw or ((tooth or teeth) adj1 (artificial or replacement)).tw
13.	Exp dental implants/ or exp dental implantation/
14	Implant$.tw
15.	(Canine adj1 (camouflage or substitut$)).tw
16.	transplant$.tw or autotransplant$.tw
17.	Retained adj1 (deciduous or primary) adj1 (teeth or tooth or dentition)
18.	6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17
Limitations	
19.	5 and 18
20.	Limit to 1970-current
21.	(animals NOT Humans).sh
20.	20 NOT 21

Key for Supplemental Tables 2-9

MLIA	Maxillary lateral incisor agenesis
MSPA	Mandibular second premolar agenesis
OHRQoL	Oral health-related quality of life
OHIP	Oral Health Impact Profile
RBB	Resin Bonded Bridge
OSC	Orthodontic Space Closure
SOI	Space Opening with Implant
SOP	Space Opening with Prosthesis
Rad.exam	Radiographic examination
Clin.exam	Clinical examination
Records	Information obtained from clinical records

Supplemental Table 2: Summary of study information for studies evaluating the management of primary teeth (n=11)

Study	Purpose	Setting	Study design	Participants	Intervention	Comparator	Outcomes	Measurement tool	Reference provided for tool	Follow up period
Maintenance of primary teeth										
Bjerklin 2000[16]	Assess longevity of treatment and health	Sweden General practice	Longitudinal Non-comparative Prospective	41 participants Aged 11-12 years 28 female, 13 male Hypodontia: MSPA	Observation of primary tooth (n=59)	None	Treatment longevity Dental health	Rad.exam: Survival of primary tooth, measurement of infraocclusion and tooth tipping, root resorption score	No	2-20 years
Bjerklin 2008[17]	Assessment longevity of treatment and health	Sweden General practice	Longitudinal Non-comparative Retrospective	99 participants Aged 12-13 years 62 female, 37 male Hypodontia: MSPA	Observation of primary teeth (n=99)	None	Treatment longevity Dental health	Rad.exam: Survival of primary tooth, measurement of infraocclusion and tooth tipping, root resorption score	Given for root res. score	1-33 years
Hvaring 2014[18]	Assess health changes in primary teeth and importance for prognosis	Norway University	Cross-sectional Non-comparative	111 participants Aged 12.6±3.6 years (range 6-25) 63 female, 48 male Hypodontia: MSPA	Observation of primary teeth (n=188) Infraocclusion (n=92)	None	Dental health	Rad.exam: Measurement of infraocclusion, presence of restoration, root resorption score	Yes	n/a
Ith-Hansen 2000[19]	Assess longevity of treatment and health	Denmark Setting not reported	Longitudinal Non-comparative Retrospective	18 participants Age "late twenties" 9 female, 9 males Hypodontia: MSPA	Observation of primary teeth (n=26)	None	Treatment longevity Dental health	Clin.exam: Survival of primary tooth, infraocclusion Rad.exam: Root resorption, tooth morphology	No	16 years
Kjaer 2008[20]	Assess dental health of primary teeth and predictive value for longevity	Denmark Dental practice	Cross-sectional Non-comparative	105 participants Aged 6.75 - 16.5years 54 female, 51 male Hypodontia: MSPA	Observation of primary teeth	None	Dental health	Rad.exam: Root resorption score	Yes	n/a
Kurol 1984[21]	Assessment longevity of treatment and health	Sweden Setting not reported	Longitudinal Non-comparative Retrospective	12 participants Mean age 10.9years (range 8.4–15.2) 5 female, 7 male Hypodontia: MSPA	Observation of primary teeth (n=20)	None	Treatment longevity Dental health	Clin.exam: Ankylosis, infraocclusion Rad.exam: Measurement of bone levels Dental casts: Infraocclsuion, occlusion	No	2 – 5 years (mean 2.7y)
Sletten 2003[22]	Assessment longevity of treatment and health	USA University	Longitudinal Non-comparative Retrospective	22 participants Mean age 36.1 years (range 21-77) 16 female, 6 male Hypodontia: MSPA	Observation of primary teeth (n=32)	None	Treatment longevity Dental health	Rad.exam: Measurement of root length Records: Tooth survival, presence of restoration	No	Group I >5y (n=27) Group II <5y

Management of primary teeth to encourage space closure										
Lindqvist 1980[23]	Success of treatment	Sweden Public Dental Health Service	Longitudinal Comparative Retrospective	144 participants Aged 5-12 years 77 female, 67 male Premolar agenesis	Planned extraction with space closure measures (n=101)	Unplanned extraction (n=43)	Dental health Function Predictors of treatment success	Rad.exam: Measurement of root resorption, tipping of teeth & bone levels Dental casts: Space closure, occlusion Functional disturbance (method unclear)	No	3 years (n=68) 4 years (n=39)
Mamopoulou 1996[24]	Success of treatment	Sweden Centre for Oral Health Sciences	Longitudinal Comparative Retrospective	11 participants Aged 11.8 years (range 10.3- 13) 7 female, 4 male Hypodontia: MSPA	Extraction of primary mandibular molar (n=13) ± maxillary molar (n=12)	Contralateral side without agenesis in cases of unilateral MSPA (n=9)	Treatment success Dental health	Rad.exam: Pancherz analysis Dental casts: Occlusal measurements	Yes	4 years (4.0-4.4y)
Northway 2004[25]	Success of treatment	USA Private Practice	Cross-sectional Comparative	83 participants Aged 8-20 years Sex distribution not reported Hypodontia: MSPA	Hemisection of lower primary molar (n=23) with or without maxillary extractions, then orthodontic treatment	1. Extraction of first premolar (n=30) 2. Extraction of second premolar (n=30) 3. Untreated historic controls	Treatment success Dental health	Rad.exam: Pitchfork analysis Dental casts: Occlusion	Yes	n/a
Valencia 2004[26]	Description of technique	Mexico Setting not reported	Experimental	34 participants Grp 1: Aged 8-9years Grp 2: Aged >10years 14 female, 20 male Hypodontia: Premolar agenesis	Controlled slicing of primary mandibular second molar (n=28)	Extraction of primary mandibular second molar (n=14) Extraction of primary maxillary second molar (n=10)	Treatment success	Clin.exam: Space closure, molar position, midline shift	No	12-18 months

Supplemental Table 3: Summary of study information for studies evaluating orthodontic space closure (OSC)

Study	Purpose	Setting	Study design	Participants	Intervention	Comparator	Outcomes	Measurement tool	Reference provided for tool	Follow up period
Rosa 2016[27]	Assess health following treatment	Italy Ortho-dontic practice	Longitudinal Comparative Retrospective	58 participants Mean age at follow up: hypodontia 33±10years, control 27±7 years 37 female, 21 male Hypodontia: MLIA	Orthodontic space closure with adjunctive restorative camouflage	None	Dental health Function Harms	Clin.exam: Periodontal (probing, bleeding, plaque, gingival, mobility), occlusal & functional TMD questionnaire	Yes	Mean 9.9±4 years
Zimmer 2009[28]	Assess outcome from treatment	Germany Ortho-dontic practice	Longitudinal Non-comparative Retrospective	25 participants Mean age at end of active tx 16.4±1.3 years 15 female, 10 male Hypodontia: MLIA	Orthodontic space closure OSC (n=25)	None	Treatment success	Dental casts: Occlusal measurements Rad.exam: Dental & skeletal measurements	No	End of orthodontic treatment
Zimmer 2007[29]	Assess outcome from treatment	Germany Ortho-dontic practice	Longitudinal Non-comparative Retrospective	17 participants Mean age at start 13.9y (12.7-16.8y) 11 female, 6 male Hypodontia: MSPA	Orthodontic space closure OSC (n=17)	None	Treatment success	Dental casts: Occlusal measurements Rad.exam: Dental & skeletal measurements	No	End of orthodontic treatment

Supplemental Table 4: Summary of study information for studies evaluating tooth-supported restorations

Study	Purpose	Setting	Study design	Participants	Intervention	Comparator	Outcomes	Measurement tools	Reference provided for tool	Follow up period
Allen 2016[30]	Survival and success of treatment	Ireland Dental Hospital	Longitudinal Non-comparative Prospective	40 participants Aged 18-21 years 18 female, 22 male Hypdontia: Mild (26), moderate (8), severe (6)	Fixed RBB following orthodontics (n=65)	None	Treatment success	Clin.exam: Survival of RBB, technical or biological complications	No	24 months
Anweigi 2013[31]	Assess treatment on QoL	Ireland University	Cross-sectional Comparative	82 participants Median age 19 years (range16-34) 43 female, 39 male Hypodontia: >4 teeth (43), ≤4 teeth (39)	Fixed RBB following orthodontics (n=40)	Agenesis patients not yet started treatment or early in orthodontic treatment (n=42)	OHRQoL	OHIP-49	Yes	n/a
Garnett 2006[32]	Survival of treatment and impact of covariates on survival	UK University	Longitudinal Non-comparative Retrospective	45 participants Mean age at time of RBB placement 17.6 years (range 13-44) 31 female, 14 male Hypodontia: MLIA	Fixed RBB (n=73): 62 cantilever, 9 fixed/fixed and 2 double abutted cantilever	None	Treatment success	Clin.exam: Survival of RBB Records: Survival (if did not attend for exam), details of covariates	No	Unclear
Hobkirk 1989[33]	Technical failure of treatment	UK Hospital	Longitudinal Non-comparative Retrospective	138 participants Age and sex not reported Hypodontia: Severe	Removable partial dentures with acrylic resin onlays	None	Treatment success	Records: Life of prostheses, technical failures	No	Up to 7 years
Spinas 2013[34]	Survival of treatment	Italy University	Longitudinal Non-comparative Retrospective	30 participants Aged 13-17 years 20 female, 10 male Hypodontia: MLIA	Fibre-reinforced composite fixed partial dentures (n=32)	None	Treatment success	Clin. exam: Margins and morphology of prosthesis, failure by structural fracture or detachment	Yes	5 years

Supplemental Table 5: Summary of study information for studies evaluating implant-supported restorations

Study	Purpose	Setting	Study design	Participants	Intervention	Comparator	Outcomes	Measurement tool	Reference provided for tool	Follow up period
Allen 2016[35]	Outcome of treatment (QoL, appearance, health)	Ireland Dental Hospital	Longitudinal Non-comparative Prospective	12 participants Mean age 19.33 ± 2.37 years 7 female, 5 male Hypodontia: Not reported	Osseo-integrated implants (n=20)	None	OHRQoL Appearance Treatment success Dental health	OHIP-20 PES/WES scores Clin.exam: Implant stability, abutment connection Rad.exam: Marginal bone levels	Yes	24 months
Creton 20103[36]	Treatment survival	Nether-lands University	Longitudinal Comparative Retrospective	294 participants Mean age approx. 20 ± 10years, 180 female, 114 male Hypodontia: Severe	Osseo-integrated implants (n=44)	Conventional restorative treatment or no treatment (n=250)	Treatment longevity	Records: Implant survival	No	2.9 years (0.1-18.3)
Degidi 2009[37]	Treatment survival and health	Italy Setting not reported	Experimental	60 participants Age at time of implant placement 31.5±11.8 years (range 18-55) 33 female, 27 males Hypodontia: MLIA	Immediate restoration of implant (n=30)	One-stage implant (n=30)	Treatment longevity Treatment success	Clin.exam: Implant survival, Papilla Index, probing depths, bleeding on probing, biological and technical complications Rad.exam: Marginal bone levels	Yes	36 months
Finnema 2005[38]	Assess treatment efficacy	Nether-lands University	Longitudinal Non-comparative Retrospective	13 participants Aged 17-30 years 7 females, 6 males Hypodontia: Severe	Dental implants (n=87) with bone grafting (n=11)	None	Treatment success Dental Health Patient experience Harms	Clin.exam: Bleeding index, Plaque index, Gingival index, probing depth Rad.exam: Marginal bone levels Questionnaire: Patient experience/ satisfaction, Mandibular Function Impairment Questionnaire (MFIQ)	Given for clinical and MFIQ	3±2 years (1-8)
Goshima 2009[39]	Functional outcome and OHRQoL following treatment	Denmark University	Cross-sectional Non-comparative	19 participants Aged 32±10 years 9 female, 9 male Hypodontia: Not reported	Implant-supported single crowns (n=39)	None	Function OHRQoL	OHIP-49 (functional domains) Mastication Index Clin.exam: Occlusion, masticatory function	Yes	1 month
Heuberer 2015[40]	Functional and aesthetic outcome from treatment	Austria University	Longitudinal Non-comparative Retrospective	18 participants Aged 8-16 years 9 female, 9 male Hypodontia: Severe	Implants (n=71)	None	Treatment longevity Treatment success	Clin.exam: Bleeding on probing, plaque Rad.exam: Implant survival, peri-implant bone loss, implant position	No	Meaning loading time 11±4.1years (1-18)

Hosseini 2013[41]	Assess treatment outcome	Denmark University	Longitudinal Comparative Prospective	59 participants Mean age 27.9±9.3 yrs 35 female, 24 males Hypodontia: variable	Single tooth implant - All ceramic (n= 52)	Single tooth implant - ceramic crown, metal abutments (n=12) Single tooth implant - metal-ceramic crown, metal abutment (n=34)	Treatment longevity Treatment success Dental health OHRQoL Appearance	Clin.exam: Implant survival, mobility, Plaque Index, Sulcus Bleeding Index, biological & technical complications Rad.exam: Marginal bone levels, marginal adaption score OHIP-49 Copenhagen Index Score	Given for Indices and OHIP-49	3 years (median 37.1 months after crown cementatn.)
Hosseini 2011[42]	Assess treatment outcome	Denmark University	Experimental	36 participants Hypodontia: Premolar agenesis	38 all-ceramic (AC) implant-supported single tooth restorations (n=38)	Metal-ceramic (MC) implant-supported single tooth restorations (n=37)	Treatment longevity Treatment success Appearance	Clin.&Rad.exam: Implant survival, biological and technical outcomes Copenhagen Index Score VAS for patient-reported assessment of appearance	No	1 year
Hu 2011[43]	Preliminary report of treatment outcome	China University	Longitudinal Non-comparative Retrospective	10 participants Mean age 33.9yrs (range 25-45y) 5 female, 5 male Hypodontia: 7 mild 2 mod., 1 severe	Single-tooth implants (n=31)	None	Dental health Treatment success	Clin.exam: Soft tissue health, prosthesis stability, function & technical complications Rad.exam: Bone levels	No	108.4 months (61-155)
King 2016[44]	Assess treatment success	Denmark Germany Italy Spain Sweden UK University	Longitudinal Non-comparative Prospective	38 participants Mean age 24 yrs 20 female, 18 male Hypodontia: Incisors	Small diameter single tooth implant (n=62)	None	Implant survival Dental health Appearance	Clin.exam: Implant stability, soft tissue health, bleeding on probing, aesthetic soft tissue score Rad exam: Marginal bone levels	No	60 months
Managano 2014[45]	Assess aesthetic outcome of treatment	Italy University	Longitudinal Comparative Retrospective	20 participants Aged 19.8-24.2yrs 11 female, 9 male Hypodontia: MLIA	Single tooth implant	Contralateral natural incisor for aesthetic comparison	Treatment success Dental health Appearance	Clin.&Rad.exam: Bone levels, biological or technical complications PES/WES	Yes	36 months
Nissan 2011[46]	Assess outcome from treatment	Israel University	Longitudinal Non-comparative Retrospective	12 participants Aged18-35yrs 10 female, 2 male Hypodontia: Unclear	Bone block-allograft (n=19) and single tooth implant (n=21)	None	Treatment longevity Treatment success	Clin.&Rad.exam: Implant survival, bone graft survival and bone gain, complications	No	30±16 months

Zarone 2006[47]	Assess treatment outcome (bone levels and soft tissues)	Italy University	Longitudinal Non-comparative Prospective	30 participants Aged 21-45 yrs 19 female, 11 male Hypodontia: MLIA	Osseo-integrated implants (n=34)	None	Marginal bone levels, peri-implant soft tissue quality	Clin.exam: Peri-implant probing, pain, mobility, soft tissue conditions (Plaque Index, Gingival Index, Bleeding on probing, Papilla Index Score) Rad.exam: Marginal bone levels	Given for soft tissue conditions	24-39 months
Pre-implant preparatory treatment										
Beyer 2007[48]	Determine ideal treatment time	Germany University	Longitudinal Non-comparative Retrospective	14 participants Mean age at start of treatment 13±1.5yrs 9 female, 5 male Hypodontia: MLIA	Orthodontic space opening for implant placement into site (n=26)	None	Treatment success	Dental casts: Incisor inclination, Alveolar ridge volume	No	Start of orthodontic treatment to time of implant placement approx. 5.5y
Eliasova 2014[49]	Determine post-treatment changes	Czech Republic University & Private Practice	Longitudinal Comparative Retrospective	55 participants Aged 11-52yrs 43 female, 12 male Hypodontia: MSPA	Orthodontic space opening with no implant (n=20, 24 sites)	Space opening with implant placement (n=20, 25 sites)	Treatment success	Dental casts: Alveolar ridge volume	No	2 or 5 years
Novackova 2011[50]	Determine treatment changes and stability	Czech Republic Private practices & Dental School	Longitudinal Comparative Retrospective	80 participants Mean age at start 18yrs (range 11.2-31.2) Sex: Not reported Hypodontia: MLIA	Space opening for prosthetic tooth replacement	Contralateral canine and lateral incisor site in unilateral agenesis	Treatment success	Dental casts: Alveolar ridge volume	No	2 or 5 years
Olsen 2010[51]	Assess outcome from treatment	USA Specialist practices	Longitudinal Non-comparative Retrospective	94 participants Age at end of ortho. Treatment 12-60yrs 78 female, 16 males Hypodontia: MLIA	Orthodontic space opening for placement of implant (n=142)	None	Treatment success	Rad.exam: Measurement of root approximation	No	Start of orthodontic treatment to implant placement
Uribe 2013[52]	Determine treatment changes and stability	USA Private practise	Longitudinal Comparative Retrospective	11 participants Mean age 16.45±5.76yrs (range 11.3-28) 4 females, 7 males Hypodontia: MLIA	Orthodontic space opening (n=13)	Comparison to contralateral side unilateral agenesis (n=6)	Treatment success	CBCT: Alveolar bone volume	No	End of orthodontic treatment
Uribe 2013[53]	Determine treatment changes and stability	USA University & Private practices	Longitudinal Comparative Retrospective	31 participants Average age pre-treatment 15±7.9yrs 23 females, 8 males Hypodontia: MLIA	Orthodontic space opening (n=45)	Contralateral side in unilateral agenesis (n=10)	Alveolar bone volume	Dental casts: Alveolar ridge volume	Given for one measurement method	End of orthodontic treatment

Supplemental Table 6: Summary of study information for studies evaluating tooth autotransplantation

Study	Purpose	Setting	Study design	Participants	Intervention	Comparator	Outcome	Measurement tool	Reference provided for tool	Follow up period
Jonsson 2004[54]	Assess long-term survival and dental health of treatment	Iceland Private Practice	Longitudinal Non-comparative Retrospective	32 participants Mean age at time of surgery 13.1yrs (range 10.7-15.10y) 19 female, 13 male Hypodontia: Premolar agenesis	Auto-transplantation of 1-2 premolars to premolar agenesis site (n=40)	None	Treatment longevity Treatment success Dental health	Survival and success based on:- Clin.exam: Transplant survival, signs of ankylosis, gingival tissues, periodontal attachment Rad. exam: Root resorption, pulpal health, alveolar bone	Given for root resorption and success criteria	2.5-22 years (mean 10.3y)
Josefsson 1999[55]	Assess treatment outcome	Sweden Oral Surgery Dept., Eastman Institute	Longitudinal Non-comparative Retrospective	80 participants Mean age at time of surgery: premolar 13.5yrs (10.2-22), Molar 16.8yrs (17.1-21) 39 female, 41 male Hypodontia: MSPA	Auto-transplantation of premolar into premolar agenesis site (n=110)	None	Treatment longevity Treatment success Dental health	Clin.&Rad.exam: Transplant survival, pulp health, ankylosis, gingival condition, mobility, periapical health, root resorption and development	No	4 years
Slagsvold 1974[56]	Assess treatment outcome (root growth)	Norway University of Oslo	Longitudinal Non-comparative Retrospective	31 participants Mean age at time of surgery 11.8yrs (range 8.5-15.5y) 18 female, 13 male Hypodontia: MSPA	Auto-transplantation of premolars into premolar agenesis site (n=34)	8 compared to contralateral premolar	Survival, Success (Root formation)	Rad.exam: Transplant survival, measurement of root length	No	Mean 6.2 years (range 3.3-13.8y)

Supplemental Table 7: Summary of included studies that compare between treatment modalities

Study	Purpose	Setting	Study design	Participants	Intervention	Comparator	Outcomes	Measurement tool	Reference provided for tool	Follow up period
Orthodontic space closure vs. space opening with restorative treatment										
Armbruster 2005[57]	Evaluate ratings of attractiveness between treatments & difference between raters	USA Local dental meeting	Cross-sectional Comparative	12 photo. subjects Hypodontia: MLIA 252 raters 212 dental professionals, 40 lay	OSC (n=3) OR SOP (n=3) OR SOI (n=3)	Non-hypodontia control (n=3)	Appearance	Rating colour photographs using scale with bipolar adjectives relating to dental attractiveness	Given for rating scale but not photos.	n/a
De-Marchi 2014[58]	Assess the smile attractiveness of treatment outcomes	Brazil University	Cross-sectional Comparative	68 photo. subjects Age 14-45 years 16 female, 52 male Hypodontia: MLIA 40 raters: 20 dentist, 20 lay Mean age 31 years (27-38) 20 female, 20 male	OSC (n=26) or SOI (n=20)	Control group without hypodontia (n=22)	Appearance	Rating smile attractiveness using colour photographs and visual analogue scale (VAS) Patient satisfaction with appearance using VAS	Yes	n/a
De-Marchi 2012[59]	Assess dental health outcome from treatments	Brazil University	Longitudinal Comparative Retrospective	68 participants Mean age – Treatment approx. 25 years, Control 21 years 52 female, 16 male Hypodontia: MLIA	SOI (n=20) or OSC (n=26)	Control without hypodontia (n=22)	Dental health	Clin.exam: Periodontal health (Plaque index, bleeding on probing, probing depth, papilla index, abfraction lesions, biotype) Questionnaire: TMD	Yes	Implant 3.54±2.39y OSC 3.90±3.48y
Nordquist 1975[60]	Assess dental health outcome from treatments	USA Setting not reported	Longitudinal Comparative Retrospective	33 participants Age & sex not reported Hypodontia: MLIA	OSC (n=39) or SOFP (n=13) or SORP (n=6)	Natural incisor (n=8)	Dental health	Clin.Exam: Periodontal health (Gingival Index, Plaque Index, Irritant Index, Periodontal Index) Clin.&Rad exam: Occlusal function	Given for perio. indices	Mean 9.8y (range 2.4–25.6y)
Pinho 2015[61]	Evaluate ratings of attractiveness between treatments & difference between raters	Portugal University and Practice	Cross-sectional Comparative	4 photo. subjects Hypodontia: MLIA 381 raters: 80 ortho., 180 dentist, 120 lay	OSC (n=2)	Orthodontic space opening with tooth replacement (n=2)	Appearance	Ranking smile attractiveness using 10-cell numeric scale with colour photographs	Given for photos.bBut not scale	n/a

Pini 2013[61]	Analyse aesthetic outcome from treatments	Brazil Setting not reported	Cross-sectional Comparative	52 participants Age and sex not given Hypodontia: MLIA	Orthodontic space closure OSC (n=18) Space opening & implant SOI (n=10)	Control group without hypodontia (n=24)	Appearance	Dental casts: Measurements of aesthetic parameters	Given for parameters	n/a
Qadri 2016[63]	Assess attractiveness of outcome from treatment	UK University and Dental Hospital	Cross-sectional Comparative	20 photo. subjects Hypodontia: MLIA 942 raters: Mean age 28±11y 776 female, 242 male	Orthodontic space closure (n=5)	Space opening with prosthetic tooth replacement (n=5)	Appearance	Web survey: Rating attractiveness of photographs using 5-point Likert scale, Choice between pairs of photographs	No	n/a
Robertsson 2010[64]	Assess perception of appearance of outcome from treatment	Sweden Setting not reported	Cross-sectional Comparative	16 photo. subjects. Hypodontia: MLIA 90 raters: 59 female, 31 male 30 Hypo., 20 non-hypo., 20 parents, 20 dentists	Orthodontic space closure OSC (n=11)	Space opening and tooth replacement (n=5)	Appearance	Rate colour photographs using visual analogue scale and interview	No	n/a
Robertsson 2000[65]	Assess appearance of health between treatment outcomes	Sweden Hospital	Longitudinal Comparative Retrospective	50 participants Mean age at follow-up 25.8 years (18.4-54.9) 36 female, 14 male Hypodontia: MLIA	Orthodontic space closure OSC (n=30)	Space opening with prosthetic tooth replacement PR (n=20)	Appearance Function Dental health	Eastman Esthetic Index Questionnaire Structured interview TMD questionnaire Clin.exam: Helkimo Index, Perio. (plaque, bleeding on probing, pocket depth)	Given for EEIQ and Helkimo Index	Mean time since completion of treatment 7.1y (0.5-13.9y)

Implant-supported vs. tooth-supported tooth replacement										
Dueled 2009[66]	Assess outcome from treatment	Denmark Private Practice	Longitudinal Comparative Retrospective	187 participants Mean age 31 years 115 female, 72 male Hypodontia: Variable	Implant-supported restoration (n=110) Tooth-supported restoration (n=19)	Control (n=58)	Treatment success Appearance OHRQoL Service delivery	Exam: Root resorption, marginal bone, mobility, peri-apical health, technical variables, aesthetic score OHIP-49 Satisfaction questionnaire	Yes	Mean 46m (3-79m) since prosthetic treatment completed
Incici 2009[67]	Assess costs associated with treatment	Switzer-land University	Longitudinal Comparative Retrospective	45 participants (22 with hypodontia) Mean age 19.3 years (16.6-24.7y) 10 female, 12 male Hypodontia: Variable	Tooth-supported (n=5) Implant-supported (n=17)	Comparison between: 1) type of restorations 2) treatment outcome between birth defect groups	Service delivery	Estimate of costs of initial treatment and maintenance	No	>5 years
Krieger 2009[68]	Assess treatment success	Switzer-land University	Longitudinal Comparative Retrospective	45 participants (22 with hypodontia) Mean age 19.3 years (16.6-24.7y) 10 female, 12 male Hypodontia: Variable	Tooth-supported (n=5) Implant-supported (n=17)	Comparison between: 1) type of restorations 2) treatment outcome between birth defect groups	Treatment success	Clin.exam: Survival, probing pocket depth, bleeding on probing, pulp health, technical complications, biological complications Rad.exam: Biological complications Records: Complications	Given for some clinical measures	>5 years

Supplemental Table 8: Summary of included studies for service provision

Study	Purpose	Setting	Study design	Participants	Intervention	Comparator	Outcomes	Measurement tool	Reference provided for tool	Follow up period
Meaney 2012[69]	Assess impact of condition and treatment	Ireland University	Cross-sectional Non-comparative	10 participants Aged 16-25 years 5 female, 5 male Hypodontia: variable	Various stages of hypodontia treatment	n/a	OHRQoL Satisfaction with care Patient experience	Qualitative interviews	Yes	n/a
Tams 2003[70]	Description of service model	UK NHS Hospital	Cross-sectional Non-comparative	400 participants Age, sex and type of hypodontia not reported	Attendance at hypodontia clinic	n/a	Service delivery Patient experience	Questionnaire Clinical efficiency: clinic running times, agreement of treatment plan, correspondence	No	n/a
O'Keeffe 2016[71]	Evaluate patient experience and satisfaction with hypodontia care	UK Dental Hospital	Cross-sectional Non-comparative	20 participants Mean age 21 years (range 16-47y) 6 females, 14 males Hypodontia: Variable	Completed orthodontic treatment but yet to commence restorative treatment	n/a	Patient experience	Qualitative interviews	Yes	n/a

Supplemental Table 9: Audits for quality improvement in service provision for hypodontia (OR = Orthodontic-Restorative)

Study	Setting	Participants	Outcome	Measurement tool
Borrie 2008[72]	Dental Hospital Scotland	80 patients Average age 23 years (range 11-60y) 38 females and 42 males Severity of hypodontia not reported	Treatment time Agreement between planned and actual treatment	Retrospective data extraction from case notes
Walker 2009[73]	Dental Hospital England	124 patients Average age 19.2 years (range 11-52y) 52% female, 48% male Mean missing teeth per patient 4.9 (range 0 - 22)	Appropriate use of clinic slots Clinic organisation	Retrospective data collection from clinical notes and the Patient Administration System (PAS)
Crawford 2010[74]	Foundation Trust Hospital England	65 patients Age and sex not reported Majority mild hypodontia but up to 12 missing teeth	Confirmation of treatment plan and treatment provider	Prospective data collection using a proforma
Parvizi 2010[75]	Dental Hospital England	62 patients Age and sex not reported (40 hypodontia, 22 other)	Appropriate use of clinic slots Availability of records Confirmation of a treatment plan	Retrospective data collection from case notes
Shah 2014[76]	Teaching Hospital England	66 hypodontia patients seen from October 2008 onwards including patients already in treatment	Time waiting to be seen for initial consultation Treatment time	Retrospective data extraction from case notes
Borrie 2014[77]	Dental Hospital Scotland	All Consultant Orthodontists in hospital orthodontic department in Scotland (21 sites)	Access to hypodontia care Confirmation treatment objectives achieved	Questionnaire
Shah 2016[78]	Dental Hospital England	Cycle 1: 46 patients Cycle 2: 55 patients Age, sex and type of hypodontia not reported	Record keeping	Cycle 1: Retrospective data collection from clinical notes Cycle 2: Prospective data collection using proforma
Wazani 2016[79]	Dental Hospital England	48 patients Age range 14-53 years 23 male and 25 female	Time waiting to be seen for initial consultation Delays between stages of care Treatment duration Record keeping	Prospective data collection using standardised proforma

Table I: Search strategy for identifying empirical research reports

Search strategy		
Electronic databases (Search date 19th December 2016)	1. Pubmed 2. Medline via Ovid (1946 onwards) 3. EMBASE via Ovid (1947 onwards) 4. Scopus 5. Web of Science a. Science Citation Index and b. Conference Indexes 6. Dissertations and Theses database.	Search terms for hypodontia AND treatment methods
	1. Cochrane Collaboration (DARE, CDSR) 2. NICE 3. SIGN 4. Trials register ww.clinicaltrials.gov	Search terms for hypodontia only
Grey literature searches	▪ Hand searching reference lists of relevant publications and reviews ▪ Additional citation searching for relevant papers identified in searches ▪ Personal contact via email to the members of two dental specialty societies (British Orthodontic Society BOS and Restorative Dentistry UK RDUK) to identify unpublished academic work ▪ Hand searching of the Clinical Effectiveness Bulletins of dental specialty societies (BOS, BSPD)	

Table II: Inclusion and exclusion criteria for study selection

	Included	Excluded
Population	People with hypodontia	People with syndromic hypodontia
	No restrictions on participants based on age, ethnicity or severity of hypodontia	Treatment for tooth loss with aetiology other than hypodontia
Intervention	Any type of dental treatment undertaken to manage hypodontia: ▪ Management of retained primary teeth ▪ Orthodontic treatment to redistribute space, alone or in combination with restorative procedures to aid/eliminate tooth replacement (fixed appliances, removable appliances) ▪ Restorative treatment for tooth replacement (fixed prostheses, removable prostheses, implant-supported restoration) or tooth camouflage ▪ Tooth auto-transplantation Any aspect of hypodontia service delivery	Simulated treatment such a treatment prediction using computer software and hypothetical treatments
		Purely laboratory-based interventions
		Future treatments still in development e.g. biological methods for growing and replacing missing teeth
Comparator	For comparative studies, any treatment listed above or no treatment	
	Non comparative studies were eligible for inclusion	
Outcomes	Any evaluation of hypodontia care (treatment methods or service delivery)	Aetiology of hypodontia
		Prevalence of hypodontia
Study design	Systematic reviews with data synthesis that produced primary summary data (e.g. meta-analysis)	Non-systematic reviews ▪ Reviews without evidence synthesis ▪ Expert opinion
	Experimental designs ▪ Randomised controlled trials ▪ Quasi-experimental studies	Case series with less than 10 participants or single case reports
	Observational studies ▪ Comparative or non-comparative ▪ Prospective or retrospective	Conference abstracts with inadequate information regarding methodology and results
	Economic studies	
	Qualitative studies	
	Quality improvement reports ▪ Audit ▪ Service evaluation	
Study character-istics	Studies originating from any country	Studies published prior to 1970
	Non-English publications	Studies not available in full text in English after reasonable attempts to obtain or translate

Table III: Summary of included studies by design

Study design			Number of studies
Experimental	Randomised controlled trial		1
	Non-randomised controlled trial		2
Observational	Longitudinal	Comparative	16
		Non-comparative	23
	Cross-sectional	Comparative	8
		Non-comparative	6
Quality improvement	Audit		8

Table IV: Synthesis of research studies by intervention with an indication of the stated purpose

Topic	No. of studies	Purpose of the study
Management of primary teeth [16-26]	11	Evaluate outcome from treatment - Longevity - Dental health - Success Description of treatment technique
Orthodontic space closure [27-29]	3	Evaluate outcome from treatment – Dental health – Success
Tooth-supported tooth replacement [30-34]	5	Evaluate outcome from treatment – Survival – Success – Technical complications – OHRQoL
Implant-supported tooth replacement [35-53]	19	Evaluate outcome from treatment – Survival – Success – Dental health – Appearance – OHRQoL Evaluate outcome from preparatory treatment – Stability – Success for facilitating future implant treatment
Tooth autotransplantation [54-56]	3	Evaluate outcome from treatment – Survival – Dental health
Comparison between treatments [57-68]	12	Evaluate outcome from treatment – Appearance – Dental health – Success – Cost-effectiveness
Service delivery [69-71]	3	Patient experience of treatment Description of service delivery model

Table V: Summary of outcomes used in audit to evaluate hypodontia care (n=7)

Outcome domain	Subdomain	No. of audits using outcome
Service delivery	Treatment duration[72, 76, 79]	3
	Clinical efficiency – Appropriate use of clinic slots [73, 75] – Clinic organisation[73] – Availability of clinical records for consultation[75] – Time waiting to be seen for consultation/ treamtent[76, 79]	 2 1 1 2
	Treatment planning – Confirmation of plan[74, 75] – Confirmation of treatment provider[74] – Adherence to treatment plan[72, 77]	 2 1 2
	Record keeping[78, 79]	2
	Access to care[77]	1

Table VI: Categorisation of research studies (n=56) based on outcome. Studies may use multiple outcomes and therefore be included more than once.

Outcome (no. of studies)	Theme (no. of studies)	Subtheme (no. of studies)
Patient-reported outcome (n=22)	Quality of life (n=6)	Oral health-related quality of life (n=6) [31, 35, 39, 41, 66, 69]
	Appearance (n=5)	Smile attractiveness (n=3) [42, 58, 66] Dental appearance (n=4) [62-64]
	Function (n=4)	Mastication (n=3) [38, 39, 41] Functional disturbance (n=1) [23]
	Harms (n=4)	Temporomandibular Dysfunction or parafunction (n=4) [23-25, 65]
	Service delivery (n=6)	Satisfaction with hypodontia care (n=6) [38, 39, 66, 69-71] Patient experience (n=3) [69-71]
Clinician-reported outcomes (n=5)	Appearance (n=5)	Smile attractiveness (n=3) [57, 64, 66,] Dental appearance (n=2) [58, 61]
Lay-reported outcomes (n=5)	Appearance (n=5)	Smile attractiveness (n=3) [58, 61, 63] Dental appearance (n=2) [57, 64]
Clinical indicators (n=49)	Appearance (n=8)	Aesthetic parameters (n=1) [62] Appearance of implant restoration (n=5) [35, 41, 42, 44, 45, 46] Soft tissue profile (n=1) [65]
	Function (n=1)	Mastication (n=1) [39]
	Dental Health (n=32)	Hard tooth tissue health (n=13) [16-23, 54, 55, 66-68] Gingival health (n=14) [27, 37, 38, 40, 42, 44, 46, 47, 54, 55, 59, 60, 65, 68] Periodontium (n=20) [16-19, 21, 22, 23, 27, 30, 37, 38, 40-43, 45, 47, 54, 55, 66] Occlusion (n=10) [16, 17, 21, 23-27, 60, 65]
	Treatment longevity (n=22)	Survival of treatment (n=22) [16, 17, 19, 21, 22, 30, 32, 33, 36-38, 40-42, 44-47, 54-56, 68]
	Treatment success (n=29)	Success of treatment (n=8) [23, 26, 28, 29, 35, 40, 47, 56,] Complications (n=14) [30, 33, 34, 35, 37, 41-43, 45-47, 55, 66, 68] Proxy markers of treatment success (n=11) [24, 25, 28, 29, 46, 48-50, 51-53]
	Service delivery (n=3)	Treatment duration (n=1) [25] Cost effectiveness (n=1) [67] Efficiency (n=1) [70]

Table VII: Measurement tools used for evaluating outcomes in hypodontia care

Outcome theme	Subtheme	Measurement tools
Quality of life	Oral health-related quality of life	Qualitative interviews [66, 69, 71]
		OHIP-49 or OHIP-20 [31, 35, 39, 42, 66]
Appearance	Smile attractiveness	Rating photographs with Visual Analogue Scale [52, 58]
		Modified Eastman Esthetic Index [65]
		Ranking photographs using 10-point numeric scale [61]
		Rating photographs using 5-point Likert scale [63]
		Choice between pair of photographs [63]
	Dental appearance	Interview questions [65]
		OHIP-49 (aesthetic domains) [66]
		Visual Analogue Scale with interview [64]
		Rating photographs with bipolar adjective scale [57]
		Rating parameters of appearance of restoration [66]
		Aesthetic parameters [62]
		Rating own satisfaction with dental appearance using VAS [58]
	Appearance of implant restoration	Copenhagen Index Score [41, 42]
		Pink Esthetic Score & White Esthetic Score (PES/WES) [35, 45]
		Gingival zenith score [44]
	Soft tissue profile	Cephalometric measures [65]
Function	Mastication	OHIP-49 (functional domains) [39, 41]
		Mastication Index [39]
		Mandibular Function Impairment Questionnaire [38]
		Masticatory ability [39]
	Functional disturbance	Functional disturbance [23]
Harms	Temporomandibular Dysfunction or parafunction	Modified HELMIKO Index [59, 65]
		Questionnaire regarding TMD symptoms [27, 65]
		TMD signs [23, 59, 65]
Service delivery	Satisfaction with hypodontia care	Questionnaire [38, 39, 66, 70]
		Qualitative interviews [69, 71]
	Patient experience	Interviews [69, 71]
	Treatment duration	Average treatment time [25]
	Cost effectiveness	Cost of treatment and maintenance [67]
	Clinic efficiency	Clinic running time [70]
		Agreement of treatment plan [70]
		Correspondence [70]
Dental Health	Hard tooth tissue health	Coronal pathology [18, 22, 67, 68]
		Pulp pathology [54, 55, 68]
		Root pathology [16-23, 54, 55, 66]
	Gingival health	Gingival Index/ gingival health [27, 38, 44, 47, 54, 55, 60]
		Irritant Index [60]
		Presence of plaque [27, 38, 40, 41, 47, 59, 60, 65]
		Probing depth [27, 37, 38, 40, 46, 47, 54, 55, 59, 60, 65, 68]
		Bleeding on probing [27, 37, 38, 40, 41, 44, 46, 47, 55, 59, 65, 68]
		Papilla Index Score [37, 47, 59]
	Periodontium	Marginal bone levels [21, 23, 35, 37, 38, 40-45, 47, 54, 66]
		Ankylosis or infraocclusion [16-19, 21-23, 54, 55,
		Tooth mobility [27, 55]
	Occlusion	Tipping of adjacent teeth [16, 17, 21, 23, 24]
		Occlusal contacts [27, 65]
		Parameters of occlusion [21, 23-26, 65]
		Parameters of functional occlusion [27, 60]

Treatment success	Survival of treatment	Survival of primary tooth [16, 17, 19, 21, 22]
		Transplant survival [54-56]
		Implant survival [36-38, 40-42, 45-47]
		Prosthesis survival [30, 32, 33, 68]
	Success of treatment	Space closure [23, 26, 28, 29]
		Implant success [35, 40, 47]
		Root development [56]
	Complications	Technical complications [30, 33, 34, 37, 41-43, 45, 66, 68]
		Biological complications [35, 37, 41-43, 45-47, 55, 66, 68]
	Proxy markers of treatment success	Alveolar bone volume [48-50, 552, 53]
		Bone gain from augmentation [46]
		Root approximation [51]
		Skeletal and dental parameters [24, 25, 28, 29]