
Article:
Donnell, C.C., Clark, M.V. and Corbett, I.P. (2022) Do children get dry socket?—The incidence and pattern of presentation of alveolar osteitis in children and adolescents following dental extractions. Oral Surgery. ISSN 1752-2471

https://doi.org/10.1111/ors.12755

Received: 30 December 2021 | Accepted: 25 May 2022

DOI: 10.1111/ors.12755

ORAL SURGERY

ORIGINAL ARTICLE

Do children get dry socket?—The incidence and pattern of presentation of alveolar osteitis in children and adolescents following dental extractions

Christopher C. Donnell[1,2] | **Megan V. Clark**[3] | **Ian P. Corbett**[4]

[1]Specialty Registrar in Paediatric Dentistry, Charles Clifford Dental Hospital, Sheffield Teaching Hospitals NHS Foundation Trust, Sheffield, UK

[2]Academic Unit of Oral Health, Dentistry and Society, School of Clinical Dentistry, University of Sheffield, Sheffield, UK

[3]Specialty Registrar in Oral Surgery, Newcastle Dental Hospital, Newcastle upon Tyne Hospitals NHS Foundation Trust, Newcastle upon Tyne, UK

[4]Consultant in Oral Surgery, Newcastle Dental Hospital, Newcastle upon Tyne Hospitals NHS Foundation Trust, Newcastle upon Tyne, UK

Correspondence
Christopher C. Donnell, Charles Clifford Dental Hospital, 76 Wellesley Road, Broomhill, Sheffield, S10 2SZ, UK.
Email: christopherdonnell@nhs.net

Abstract

Background: Alveolar osteitis (AO) is widely reported as the most common post-operative complication following surgical and non-surgical exodontia. Despite being one of the most studied complications in dentistry, there is no established consensus on its aetiology, alongside a relative paucity of studies looking exclusively into AO incidence in children and adolescents.

Objectives: To determine the incidence, risk factors and pattern of presentation of AO in children and adolescents following exodontia, as well as identifying concepts and theories to provide a basis regarding why such a common post-operative complication reportedly manifests so rarely in the paediatric population.

Methods: This cross-sectional analysis forms part of a prospective service evaluation of the exodontia service provided by Newcastle Dental Hospital. All patients aged 5–16 who underwent dental extractions of deciduous and/or permanent teeth under general anaesthetic (GA) between 15 June 2020 and the 15 July 2020 were telephoned 1 week following their procedure to determine if any had developed post-operative complications. Data were cleaned manually and analysed using descriptive statistics, exploratory analysis with chi-squared tests and multivariable analyses. A scoping review was performed using the PubMed, OVID Medline and Scopus databases.

Results: Four of 150 patients (2.8%) developed AO and reported extreme pain which began 2–3 days after removal, lasted 2 days after onset, and were all associated with the non-surgical removal of lower first permanent molar teeth. All patients who developed AO were female and aged between 9 and 10 years old. Mandibular sockets were significantly associated with development of AO ($p = 0.026$).

Conclusions: Despite the belief that AO rarely manifests in children, the incidence of paediatric AO in this study is in line with that of AO found in the adult literature. The literature is inconsistent and conflicting regarding current understanding of AO. As far as possible, an atraumatic approach to exodontia should be adopted. We have proposed four underlying concepts which may benefit from future research given the paucity of research exclusively into dry socket in children and adolescents.

KEYWORDS
adolescents, aetiology, alveolar osteitis, children, dry socket, exodontia, extractions, oral surgery, paediatric dentistry, risk factors

INTRODUCTION

Alveolar osteitis (AO), styled colloquially as 'dry socket', is widely reported as the most common post-operative complication following surgical and non-surgical exodontia.[1–3] The term 'dry socket' was first reported in 1896 by Crawford,[4] following difficult removal of a mandibular third molar. Despite being one of the most studied complications in dentistry, there is no established consensus on its aetiology, hence the condition is described inconsistently in the literature as: localised osteitis, post-operative alveolar osteitis, alveolagia, alveolar sicca dolorosa, septic socket, necrotic socket, localised osteomyelitis and fibrinolytic alveolitis.[1,5,6]

The reported incidence of AO in the adult population varies widely in the literature (1%–45%), however, a recent Cochrane review reported the incidence between 0.5% and 5% for routine, non-surgical extractions.[2,6,7] Surgical extractions have been reported to increase the incidence of AO 10-fold.[2,8] The literature is replete with varying definitions of AO, usually owing to inconsistent diagnostic criteria, however, Blum devised a standardised definition that could be used to universally describe the condition: "*postoperative pain in and around the extraction site, which increases in severity at any time between 1 and 3 days after the extraction accompanied by a partially or totally disintegrated blood clot within the alveolar socket with or without halitosis*".[2] Clinically the socket may appear partially or completely empty, covered with a greyish-yellow slough and/or necrotic tissue.[5]

Many researchers have studied the process by which AO develops, however, the exact pathophysiology is unclear. Birn's seminal work into his 'fibrinolytic theory', developed in the 1970s remains the nucleus of current theories surrounding dry socket pathogenesis.[5,9,10] Birn coined the term 'fibrinolytic alveolitis' as he postulated that the localised trauma of dental extractions causes the alveolar bone or adjacent tissues to release stable tissue activators, which convert plasminogen to plasmin, a fibrinolytic agent. This in turn dissolves the blood clot in the socket, releasing kinins from kininogens, resulting in the formation of pain. Birn's theory established that AO is unlikely to develop in the first 24 h after extraction, as the blood clot contains anti-plasmin which must first be consumed before clot dissolution can occur.[2,5,9–11]

Post-operative pain associated with AO is often persistent and refractory to analgesics, resulting in a significant burden to patients as a result of repeat return visits for symptomatic pain relief and management.[6,12] Dry socket is reported to be extremely rare in children and there appears to be a relative paucity in the literature of studies looking into AO incidence in children and adolescents.[13,14]

This study aims to determine the incidence, risk factors and pattern of presentation of AO in children and adolescents following exodontia, as well as identifying concepts and theories through a scoping review to evaluate the basis for the commonly held belief that such a common post-operative complication in adults manifests so rarely in the paediatric population.

Clinical Relevance

- *Scientific Rationale for Study*: The evidence base surrounding alveolar osteitis (AO [dry socket]) is almost exclusively concerned with adult patients (18+ years). Despite being one of the most studied dental complications, little is written in the literature about its presentation in children and adolescents.
- *Principle Findings*: Incidence of dry socket in this study was comparable to that in the adult literature. Four concepts regarding AO development in children are proposed following a scoping review and may merit further research, given the paucity of research exclusively into dry socket in children and adolescents.
- *Practical Implications*: AO may well be an under-reported phenomenon in children and adolescents. As with the adult population, an atraumatic approach to exodontia should be taken as much as possible to reduce the risk of AO development.

METHODS AND MATERIALS

The Child Dental Health (CDH) department at Newcastle Dental Hospital (NDH) provides paediatric dental services to around 600,000 children aged 0–16 across Northeast England and North Cumbria (NENC).[15,16] This cross-sectional analysis forms part of a prospective service evaluation registered with the Newcastle upon Tyne Hospitals (NUTH) Clinical Effectiveness Register (Ref: 10150). Ethical approval for the study was granted by the Newcastle University Research Ethics Committee (Ref: 3692/2020).

The study population included all patients aged 5–16 who underwent dental extractions of deciduous and/or permanent teeth under general anaesthetic (GA) between 15 June 2020 and 15 July 2020. At the initial consultation, patients and parents/guardians were informed that a telephone review would be performed 1 week following the procedure. This was to limit the need for unnecessary travel back to NDH during the coronavirus pandemic. Contact details were confirmed on the day of attendance to theatre and a reminder issued regarding the planned telephone review.

Attention was drawn to the telephone number on the post-operative information leaflet which would be the same number used for telephone review.

Theatre logbooks were used to identify patients for subsequent telephone review. Anonymised data were collected by two researchers (CD and MC). Patient records and the operation note were used to identify required information. Parameters recorded included (but not limited to): age, sex, ethnicity, medical history, caries status, surgical procedure, number of teeth removed, tooth type, operator level and peri-operative complications.

Telephone reviews were carried out by CD 7 days following GA to establish post-operative status. Parents/guardians were asked if patients had developed any post-operative complications such as pain, bleeding, bruising, swelling and infection. Signs and symptoms pathognomonic of alveolar osteitis such as severe throbbing pain at least 24 h after extraction, halitosis, bad taste in mouth and any visible loss of blood clot were dispersed throughout questioning in a predetermined pattern, to ensure a consistent, reliable approach was undertaken and recorded using a proforma. Further information such as onset of symptoms (days post-op), site(s) affected and management (if applicable) was also recorded. Data were input into a Microsoft Excel spreadsheet (Microsoft Excel for Mac 2016, Version 16.3820061401). Data were cleaned manually and analysed in Statistical Package for the Social Sciences (Mac Version 26.0.0.0; SPSS Inc.) using descriptive statistics, exploratory bivariate analysis with chi-squared tests ($p < 0.05$) and multiple logistic regression analysis to test for associations between selected variables after adjusting for the effect of others using a Bonferroni correction ($p < 0.0083$ [six variables]).

Given the predicted paucity of research in the field and the need to rapidly review evidence and analyse knowledge gaps, a scoping review of the literature was undertaken, and database searches were performed using PubMed, OVID Medline and Scopus alongside a generalised search-engine generated (Google) search. The scoping review question was ascertained using the 'PICO' framework—"In (P) children and adolescents (I) undergoing exodontia, (C) compared with the adult population, (O) what is the incidence of dry socket?" An example search strategy is shown in Box 1. For the purpose of this review, inclusion criteria defined children and adolescents as being 18 years and under, in addition to no restriction on study design or date of publication. Further inclusion criteria consisted of articles available in English; articles concerning 'dry socket' or its associated terminology; all grey literature accepted; searches covered the period from database establishment to date of database search. The included search terms combined MeSH terms and key concepts based on the research area. Exclusion criteria included no access past the title and abstract; participants over the age of 18; and where no translation was available into the English language. No automation tools were used during any stage of the scoping review.

The reference lists of studies were also manually examined for eligible studies not obtained through initial database searching. A search of the Scopus database was performed

BOX 1 Example database search strategy

1. exp *Dry Socket/
2. (Alveolar osteitis or dry socket or localised alveolar osteitis or localised osteitis or alveolagia or alveolar sicca dolorosa or septic socket or necrotic socket or localised osteomyelitis or fibrinolytic alveolitis).ti,kw.
3. 1 or 2
4. Limit 3 to ("adult (19 to 44 years)" or "middle aged (45 plus years)" or "all aged (65 and over)")
5. 4 not (child* or paediatric* or pediatri*).mp. [mp = title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
6. Limit 5 to english language
7. Limit 3 to (humans and "all child (0 to 18 years)" and (children or children - focussed))
8. 4 not 7
9. Limit 8 to english language
10. Limit 7 to english language
11. (Treatment or therap* or management or aetiology).ti,kw.
12. 3 and 11
13. 12 not (9 or 10)
14. Limit 13 to english language
15. Limit 14 to ("therapy (best balance of sensitivity and specificity)" or "causation-aetiology (best balance of sensitivity and specificity)")
16. Limit 3 to ("therapy (best balance of sensitivity and specificity)" or "causation-aetiology (best balance of sensitivity and specificity)")
17. 16 not (9 or 10)
18. Limit 17 to english language
19. (Aetiology or aetiology).ti.
20. 3 and 19
21. 18 or 20
22. Limit 21 to english language
23. 22 not (9 or 10)

with the same key words alongside adjustments to match the features of the database search function. The grey literature such as Open Grey, Ethos and Nexis were searched using the same terms used in the Scopus search. Following removal of duplicates, titles and abstracts were screened and subsequent full text review was carried out independently by two reviewers (CD and MC) against the inclusion/exclusion criteria. Should a disagreement arise, this would be resolved by consensus and/or a third reviewer (IC).

RESULTS

One hundred and fifty patients met the age criteria during the study period and were included in the analysis. The mean age of all children undergoing treatment was 7.03 years (Range 5–14, SD 2.65). Seventy-eight (52%) children were female and 72 (48%) male. One hundred per cent (n = 150) of children had their treatment performed under general anaesthetic. The majority of children treated were White British (n = 113; 75.3%). Ninety-seven (64.7%) patients were considered medically fit and well, with nine (6%) having asthma and 20 (13.3%) patients having a diagnosis of attention deficit hyperactivity disorder (ADHD) or autism spectrum disorder (ASD).

Caries was the overwhelming clinical justification for removal of teeth with 88 (58.7%) of patients being referred for this alone. Thirty-seven patients (24.6%) had caries and molar incisor hypomineralisation (MIH) as the justification and nine patients (6%) were referred due to MIH alone. Only ten procedures (6.7%) involved surgical removal. Number of teeth removed ranged from 1 to 16 (mean 6.93, SD 3.73). The most common number of teeth removed was six (n = 22; 14.7%). Deciduous teeth were the most common teeth removed (n = 87; 58%), with 11 patients (7.3%) having adult teeth extracted, and 52 (34.7%) having a mixture of adult and deciduous teeth removed (Table 1).

Overall, 107 patients (71.3%) had teeth removed by a consultant, with 41 patients (27.4%) treated by a Specialist or Specialty Registrar. There were no peri-operative surgical complications reported. Only 12 patients (8%) reported post-operative complications: infection (n = 10) and swelling (n = 2). Four (2.8%) of these patients reported additional symptoms consistent with dry socket; extreme pain which began 2–3 days after removal, lasted for 2 days after onset, and were all associated with the non-surgical removal of lower first permanent molar teeth. All patients who reported dry socket symptoms were female and aged between 9 and 10 years old and loss of the clot was confirmed following clinical examination by their general dental practitioner (GDP) (Table 2). As all treatment was carried out during the first wave of the COVID-19 pandemic, all patients with dry socket symptoms were managed by their GDP: three (75%) received antibiotics and had the sockets irrigated with saline and dressed with alveogyl; one (25%) did not receive antibiotics but did have the socket irrigated and dressed.

TABLE 1 Independent variables results

Independent variable	Outcome n(%)
Sex	
Male	78 (52)
Female	72 (48)
Ethnicity	
White	113 (75.3)
Asian	3 (2)
Mixed/multiple ethnic groups	7 (4.7)
Black, African, Caribbean	3 (2)
Other[a]	24 (16)
Medical history	
Fit and well	97 (64.7)
ASD/ADHD	20 (13.3)
Asthma	9 (6)
Other[c]	24 (16)
Indication for treatment	
Caries	88 (58.7)
Molar incisor hypomineralisation (MIH)	9 (6)
Caries and MIH	37 (24.6)
Other[b]	16 (11.7)
Surgical procedure	
Yes	10 (6.7)
No	140 (93.3)
Tooth type removed	
Deciduous	87 (58)
Permanent	11 (7.3)
Mix	51 (34.7)
Operator level	
Consultant	107 (71.3)
Specialist	4 (2.7)
Specialty registrar	37 (24.7)
Dental core trainee	1 (0.7)
General professional trainee	1 (0.7)
Post-operative complications	
No	137 (91.3)
Yes	13 (8.7)
Dry socket symptoms	
No	146 (97.3)
Yes	4 (2.7)

[a]Not reported on the system.

[b]Trauma, unerupted/ectopic canine, supernumerary, orthodontic extractions, infraocclusion.

[c]Eczema, developmental delay, Crohn's disease, Epilepsy, gastro-oesophageal reflux disease (GORD), Factor V Leiden, Ehlers–Danlos syndrome, ventricular septal defect (VSD), 1q21.1 microduplication, motor tics.

A logistic regression was conducted to assess whether the risk model, with six predictors, varied significantly with the development of dry socket. The logistic regression model was statistically significant when all independent variables were

TABLE 2 Variables associated with formation of dry socket

Variable	Outcome *n*(%)
Sex	
Female	4 (100)
Age (years)	
9	2 (50)
10	2 (50)
Ethnicity	
White	3 (75)
Mixed/multiple ethnic groups	1 (25)
Medical history	
Fit and well	2 (50)
GORD	1 (25)
Motor tics	1 (25)
Indication for treatment	
Caries and MIH	4 (100)
Surgical procedure	
No	4 (100)
Socket affected	
LL6	2 (50)
LR6	2 (50)
Operator level	
Consultant	3 (75)
Specialty registrar	1 (25)
Post-operative onset (days)	
2	3 (75)
3	1 (25)
Post-operative complications	
Infection	1 (25)
Swelling	2 (50)
Localised throbbing pain not responding to analgesics	4 (100)
Loss of blood clot	4 (100)
Bad taste	4 (100)
Halitosis	2 (50)
Management	
Socket irrigation	4 (100)
Alveogyl	4 (100)
Antibiotics	3 (75)

considered together - χ^2 (6) = 79.43; $p < 0.001$. Regression analysis showed a statistically significant association between gender ($p = 0.002$; OR 3.5) and tooth type ($p = 0.004$; OR 2.9) and the development of dry socket (Table 3). None of the other variables in the regression were calculated to have a statistically significant relationship with dry socket occurrence. When patients were grouped into single-extraction and multiple extraction cases, there was no significant difference between the two groups and development of dry socket (X^2 [1] = 3.636, $p = 0.748$). There was a significant association between development of dry socket and tooth site, with mandibular sockets significantly more likely to develop symptoms of alveolar osteitis than maxillary sockets (X^2 [1] = 6.315, $p = 0.026$).

A total of 553 articles were identified through searching electronic databases, including grey literature, Google and manual searching of reference lists. A summary of the process is outlined in Figure 1, based on the 2020 PRISMA guidelines.[17] After removing duplicates, 479 were screened by title and abstract. Seventy-four articles underwent full-text review, following which none met the inclusion criteria. There were no disagreements between reviewers. Reasons for exclusion were varied and included articles only being concerned with management ($n = 39$) or prevention ($n = 9$) of dry socket, not specific to children aged 0–16 ($n = 21$) and only being concerned with third molars ($n = 5$).

DISCUSSION

Alveolar osteitis is a common post-operative complication with considerable clinical importance, given the implications on cost and time efficiency to clinicians, in addition to sustained discomfort for patients.[6,18] To our knowledge, this is the first study to exclusively investigate the incidence and pattern of presentation of paediatric alveolar osteitis (PAO) following exodontia in paediatric patients. Our literature review followed a robust methodology and employed an extensive search strategy, given the projected paucity of relevant studies. Despite no studies meeting the broad inclusion criteria for narrative synthesis, a narrative review enabled identification of concepts and theories that provide a basis regarding why such a common post-operative complication manifests so rarely in the paediatric population, as well as highlighting areas for future research.

The incidence of PAO established in this study (2.8%) is in line with that reported in the AO adult literature (0.5%–5%).[7] Two previous studies, which had a very small, non-descriptive sample of teenagers among a larger adult sample, found no (0%) incidence of PAO in their cohort.[12,18] Studies by Oginni et al.[19] (range 4–92 years), Singh et al.[20] (range 12–79 years) and Bortoluzzi et al.[21] (range 11–79 years) all included paediatric patients in their participant cohort, however, failed to provide any further detail regarding age in their outcomes. One study by Simon and Matee[22] reported post-extraction complications in five patients aged 10–14, however, failed to inform the reader if these were related to AO or another complication. Little agreement was found in the literature with regards the effect of age on AO, with the general axiom that risk increases as age increases, especially in patients aged 18 and over.[8,23–25] Some authors attribute this to the presence of well-developed alveolar bone and the relative absence of periodontal disease in those in their third and fourth decades of life, which may increase the difficulty of tooth extraction.[18,19,26]

Only female patients ($n = 4$) developed PAO in this study, which is consistent with findings in the adult literature

TABLE 3 Logistic regression model for development of dry socket

Variable	Regression coefficient (β)	OR (95% CI)	p-value
Constant	3.27	-	<0.001*
Age > 9	−0.04	0.8 (0.5–2.2)	0.724
Female sex	1.67	3.5 (1.2–7.8)	0.002*
Indication for Extraction - Caries	0.05	1.2 (0.3–2.6)	0.814
Junior operator	0.62	1.1 (0.3–2.8)	0.421
Ethnicity - White	−0.07	0.9 (0.4–2.5)	0.662
Molar tooth	1.36	2.9 (0.7–6.3)	0.004*

Note: Hosmer and Lemeshow Test: $\chi^2 = 79.43$; df = 5; p-value<0.001.

Abbreviations: CI, Confidence Interval; OR, Odds Ratio.

*p-value <0.0083 following Bonferroni correction denotes statistical significance.

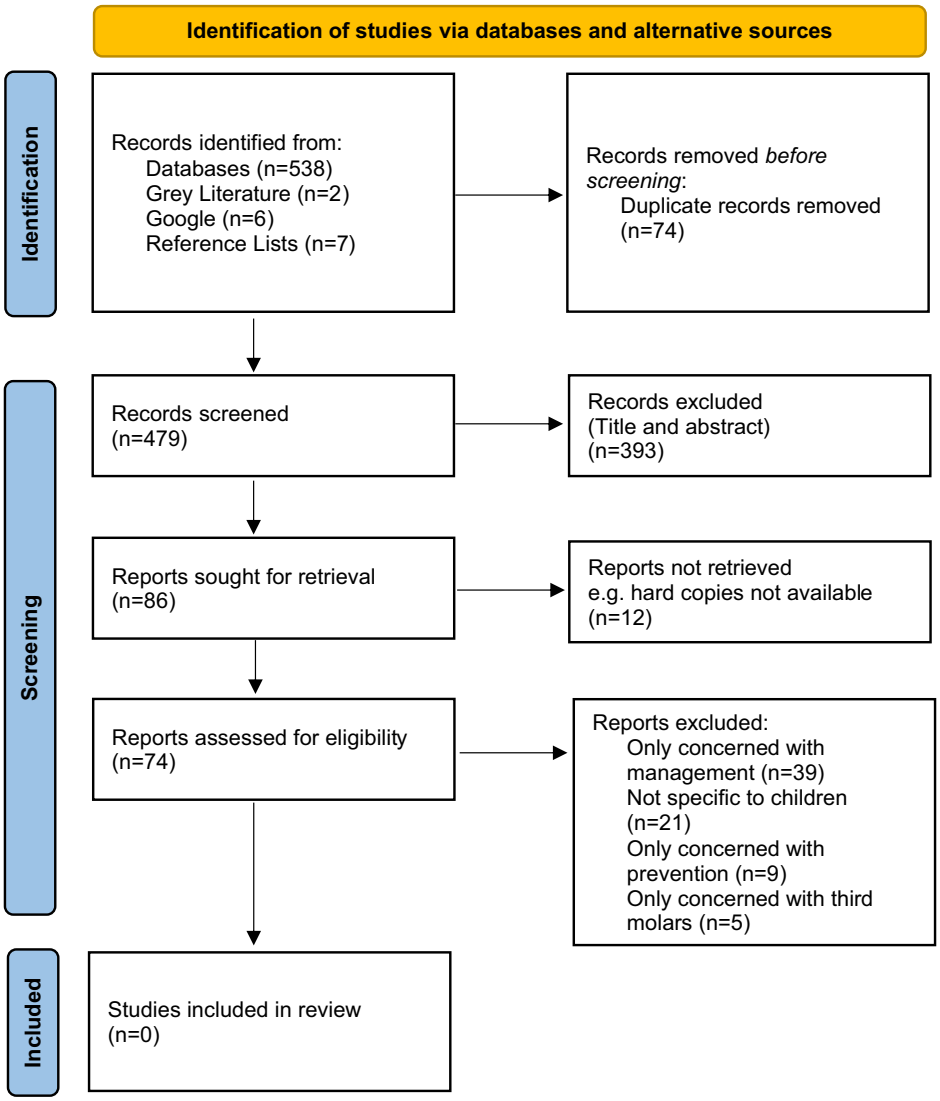

FIGURE 1 PRISMA 2020 flow chart

regarding a higher rate of AO in female patients.[5,27–29] In adult female patients this has been attributed to the use of oral contraceptives (OC), however, a recent sensitivity meta-analysis by Bienek and Filliben[30] and a randomised clinical trial by Eshghpour et al.[31] found that even without use of OC, females had a higher risk of developing AO than males. In addition, Bienek and Filliben[30] also suggest a possible causality between oestrogen-related hormones and development of dry socket, which may have some bearing on our cases, given that early (not precocious) puberty can begin in

female patients as early as 8 years old.[32] The body's response to pain has been shown to vary throughout life, particularly when there is an increase or decrease in hormone levels, with studies that looked purely at biological sex showing that during puberty, the incidence of pain conditions rises more in females than males.[33] Pain is an important symptom in AO diagnosis and studies show that not only do females suffer more painful conditions than males, the intensity and burden of pain is actually greater in female patients.[34–36] In anaesthesia research it is generally accepted that females possess a higher pain threshold than males, with a recent study by Martin et al.[37] not only confirming this stance, but they also found that males significantly anticipate past pain more than females, hence, a higher incidence of AO in female patients may result, as they have been shown to be more likely to engage in health care-seeking behaviours, thereby reporting more symptoms as a direct result of seeking AO management.[38]

Levitin et al.[39] recently mined electronic dental records to investigate risk factors associated with development of AO following exodontia; they found significant association between patients who had a complex medical history and development of AO. In our study, two patients who developed PAO had an associated medical comorbidity (Table 2). In addition to underlying medical history, studies have also investigated the relationship between justification for extraction and AO incidence, with a higher rate observed when teeth are removed for therapeutic reasons (e.g., the presence of caries and/or apical infection) than for asymptomatic, prophylactic reasons.[40] All patients in our study who developed PAO had a pre-extraction diagnosis of both caries and MIH, which may further compound the reported link between poor oral hygiene and development of AO, given the known association between sub-optimal oral hygiene and dental caries in children.[41,42]

There is limited evidence in the literature with regards the effect of single versus multiple extractions in the development of AO, with some studies indicating a higher prevalence of AO following single extractions.[18,26,43] We found no significant difference ($p = 0.748$) between patients grouped into single-extraction and multiple extraction cases in our study, however, any differences in the literature may possibly be due to less pain tolerance in patients requiring single extractions compared to those whose teeth have deteriorated to such a degree that multiple extractions are required, such as when children are waiting extended periods of time for removal under general anaesthetic.[8,18,26] We did, however, find a significant association ($p = 0.026$) between development of AO and tooth site, with mandibular sockets significantly more likely to develop AO than maxillary sockets, with many studies in the literature also reporting increased incidence of AO specifically in the mandibular molar region, possibly related to increased bone density,[18,19,26,43] and therefore more force being required for exodontia. None of the instances of PAO in our study were associated with surgical extractions, hence, as far as possible, as atraumatic an approach as possible to all exodontia should be undertaken.

Many findings in the literature hint at a relationship between operator level and development of AO, highlighted by studies in which less-experienced, junior operators had greater incidence of AO following exodontia than their consultant counterparts, thought to be due, in part, to an increase in localised trauma to the extraction site.[1,44–46] The set of teeth (deciduous or permanent) involved also appears to play a role in the development of AO. Our findings agree with those in the wider literature in that no deciduous tooth extraction resulted in PAO, most likely due to the absence of a true socket given the presence of the permanent successor underneath.[12,18,19] The authors hypothesise that should a deciduous extraction result in development of PAO, it may be due to hypodontia, particularly in the lower premolar region, where a true socket would be present and aligns with the findings in the literature, where the premolar region has been shown to be the next most common site for development of AO after the molar region.[19]

While the chief aim of this paper was to determine the incidence, risk factors and pattern of presentation of AO, we feel some mention must go towards management. Arguments in the literature are directed primarily towards the prompt relief of pain, given it is the most common symptom encountered with AO.[5] As such, studies advocate interventions geared at local delivery which achieve a greater concentration of the material in the affected area, than would be achieved through systemic delivery.[2,5] All patients who developed PAO had the sockets irrigated with saline and dressed with *Alveogyl* (Septodont, Kent, United Kingdom [UK]); a eugenol-based, non-resorbable obtundent dressing and the recommended first-line management of AO in the United Kingdom.[47–49] *Alveogyl* is the reformulated version of *Alvogyl*, which was discontinued in 2012 and no longer contains the constituents butamben and iodoform.[50] No studies were found regarding the effect of *Alveogyl*, however, research into *Alvogyl* has revealed it to be a very effective means of managing AO, although the socket must not be overpacked to prevent retardation of the healing process.[49,51] While not directly contraindicated for use in children, the manufacturers information leaflet for *Alvogyl* previously stated it was not to be used "*on deciduous teeth (children under 12 years of age)*",[47,52] which may be due to the known potential for allergic reaction and tooth staining with materials such as iodoform.[53] It is important to note that the redeveloped *Alveogyl* no longer carries the same warning message.[52]

Proposed aetiology in paediatric patients

Oral microorganisms

Based on the information accrued in the literature, most studies support the narrative that bacterial presence, alongside sub-optimal oral hygiene, are two key risk factors for development of AO. It has been shown that the frequency of AO increases with poor oral hygiene, most notably in adult patients with

pre-existing local infections and/or periodontal disease.[8,41] This is further strengthened by the proven reduction of AO incidence in conjunction with antibacterial measures.[2] With regards to why AO, such a common post-operative complication, manifests so rarely in the paediatric population, the most relevant work remains that uncovered by Nitzan et al,[13,14] who found that cultures of the anaerobe *Treponema denticola*, known to be a putative micro-organism associated with periodontal disease, were linked to 'high plasmin-like fibrinolytic activities', which result in clot disintegration.[2,13,14] *Treponema denticola* rarely, if ever, colonises the mouth of children and adolescents,[1,2,8,13,14] hence this may be one of the key aetiological factors of such a low incidence of PAO.

Trauma theory

Many studies postulate that an increase in the difficulty of an extraction may in turn increase the trauma that the socket and surrounding tissues experience during the procedure. The more challenging a procedure is also increases the extraction time, resulting in prolonged trauma and inflammation of the surrounding alveolar bone marrow, where marrow cells then precipitate fibrinolysis by releasing direct tissue activators into the alveolus, a key element in Birn's 'fibrinolytic theory'.[9] Surgical extractions are known to cause localised trauma through raising of a mucoperiosteal flap and removal of alveolar bone. Surgical removal has long been considered to increase the risk of AO, 10-fold in some cases, with a further association postulated between increased extraction trauma, difficulty of the procedure and the experience the operator possesses.[8–10,19,23] Extractions of deciduous and permanent teeth in children and adolescents rarely present a significant challenge for the operator; this is in the part due to the more 'flexible' nature of the maxillary and mandibular bone, where the osteoid density of the bone is less than that of an adult, due to the presence of more Haversian canals.[54] This enables the teeth to be removed without fracturing, reducing the need for: surgical extraction; excessive irrigation and curettage of the site; leaving any bone or root fragments in-situ, all factors previously postulated to increase the development of AO.[8–10,49]

Local blood perfusion and anaesthesia

There are two main schools of thought regarding blood perfusion to extraction sites and development of AO: reduced vasculature and the use of vasoconstrictors in local anaesthetic (LA).[9,10,49] Some authors postulate that increased bone density, such as that in the posterior mandible, results in reduced perfusion of blood.[9,10,18,49] Others report that reduced local perfusion and development of AO is due to the injection technique and vasoconstriction produced by local anaesthetic agents leading to reduced tissue oxygenation and insufficient clot formation.[49] Both these theories have been discredited, however, in that, the mandibular molar region has been shown to be one of the most richly vascularised regions in the mandible and furthermore, AO has developed in patients who have undergone both block and infiltration LA techniques as well as GA exodontia without use of local anaesthetic.[9] Moreover, local ischaemia caused by local anaesthetic only has a short duration of around 1–2 hours, thus ensuring the integrity of the blood clot.[9,10,49] Despite it being a very commonly discussed theory, there is no evidence in the literature that physical dislodgement of the blood clot contributes to the development of AO.[2,8] Reduced vasculature within the maxilla and mandible increases with age, hence in the paediatric population, growing bones have a rich vascular supply with excellent perfusion, further reducing the risk of developing PAO.[55]

Psychosocial factors

The 2013 Children's Dental Health Survey found that over half of adolescents in the United Kingdom reported moderate dental anxiety, with around a fifth (17%–21%) of 5 and 8-year-olds moderately-to-extremely dentally anxious.[56] Children with dental fear and anxiety (DFA) try all and any means to avoid and/or delay dental treatment, especially exodontia.[57] As such, the prolonged discomfort caused by AO may simply serve to enforce already negative fears and connotations surrounding dental treatment and children with DFA may therefore underreport symptoms of AO to avoid a return to the dental environment.[6]

STRENGTHS AND LIMITATIONS

With regards the literature search, despite no studies meeting the broad inclusion criteria, a major strength of this work is the extensive and comprehensive search strategy employed across both databases as well as the grey literature. Many of the comparisons drawn are to the adult populace, given the distinct paucity of studies looking wholly at the paediatric population. Only studies available in English were included, which may introduce an element of evidence selection bias. AO is also inconsistently described in the literature, often due to a lack of absolute and objective criteria, which makes it difficult to draw sound comparisons and conclusions.

The majority of studies included in the narrative review assessed the incidence of AO in secondary care. Given the large volume of exodontia performed by various levels of dental practitioner daily in primary care, AO could be a widely underreported phenomenon in children and adolescents.

Data were collected on all paediatric patients undergoing general anaesthetic exodontia over a 1-month period. Although no sample size calculation was carried out prior to study commencement, the final sample size was sufficient to comply with the generally accepted 'rule of thumb' to ensure at least 10 events per variable (EPV) being analysed; our six regression variables (age, gender, indication for extraction, operator level, ethnicity, tooth type) had 25 EPV.[58] Although our sample size is consistent with a

number of previous studies in the literature, an appropriate sample size calculation should be performed in any future studies to allow for more precise estimates of variable effects.[59]

The method of reporting dry socket relied solely on parent-reported symptoms whereas 'true' AO is confirmed on clinical examination by an expert professional whose diagnostic capacity had been contrasted beforehand—given this research was performed during the COVID-19 pandemic, clinical signs and symptoms were only confirmed for those patients who attended their GDP for AO management. This study looked only at patients in NENC, as such caution must be taken with regards the generalisability to the rest of the United Kingdom.

We did not account for socioeconomic status (SES) or a patient's index of multiple deprivation (IMD) as part of this study. Oginni et al.[19] previously found a relationship between low SES and increased development of AO; hence this is a definite area for future research. We have highlighted four key concepts in paediatric AO aetiology which merit further investigation into how young patients are so resistant to development of AO following exodontia.

CONCLUSIONS

Despite the majority of the literature suggesting AO rarely manifests in children and adolescents, the incidence of PAO in this study is in line with that of AO found in the adult population (>18 years), as well as a higher incidence in female patients and mandibular molar sockets. As atraumatic an approach as possible to all exodontia should be undertaken. Even with many years of research, the literature is inconsistent and conflicting regarding current understanding of AO. From our literature review we propose four concepts which may benefit from future research and perhaps enable stronger inferences to be drawn from a phenomenon seldom studied exclusively in the paediatric population.

AUTHOR CONTRIBUTIONS

CD contributed to study conception and design, paper acquisition, data extraction and interpretation, figures and tables, drafting, development, revision and approval of the manuscript. MC contributed to paper acquisition, data extraction and interpretation, figures and tables, drafting, development, revision and approval of the manuscript. IC contributed to study design, data interpretation, drafting development, revision and approval of the manuscript.

ACKNOWLEDGEMENT

The authors thank Peter Folly, Library Manager at the British Dental Association, for his support with the literature search strategies.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ORCID

Christopher C. Donnell https://orcid.org/0000-0003-3424-5025
Megan V. Clark https://orcid.org/0000-0002-7635-8928

REFERENCES

1. Cardoso CL, Rodrigues MT, Ferreira Júnior O, Garlet GP, de Carvalho PSP. Clinical concepts of dry socket. J Oral Maxillofac Surg. 2010;68(8):1922–32. https://doi.org/10.1016/j.joms.2009.09.085
2. Blum IR. Contemporary views on dry socket (alveolar osteitis): a clinical appraisal of standardization, aetiopathogenesis and management: a critical review. Int J Oral Maxillofac Surg. 2002;31(3):309–17.
3. Noroozi AR, Philbert RF. Modern concepts in understanding and management of the "dry socket" syndrome: comprehensive review of the literature. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2009;107(1):30–5.
4. Crawford JY. Dry socket. Dent Cosmos. 1896;38:929–31.
5. Ogunlewe MO, Adeyemo WL, Ladeinde AL, Taiwo OA. Incidence and pattern of presentation of dry socket following non-surgical tooth extraction. Nig Q J Hosp Med. 2007;17(4):126–30.
6. Ghosh A, Aggarwal VR, Moore R. Aetiology, prevention and management of alveolar osteitis—a scoping review. J Oral Rehabil. 2022;49(1):103–13. https://doi.org/10.1111/joor.13268
7. Daly B, Sharif MO, Newton T, Jones K, Worthington HV, Cochrane Oral Health Group. Local interventions for the management of alveolar osteitis (dry socket). Cochrane Database Syst Rev. 2012;12:CD006968.
8. Kolokythas A, Olech E, Miloro M. Alveolar osteitis: a comprehensive review of concepts and controversies. Int J Dent. 2010;2010:1–10. https://doi.org/10.1155/2010/249073
9. Birn H. Etiology and pathogenesis of fibrinolytic alveolitis ('dry socket'). Int J Oral Surg. 1973;2(5):211–63.
10. Birn H. Bacteria and fibrinolytic activity in dry socket. Acta Odontol Scand. 1970;28(6):773–83.
11. Vezeau PJ. Dental extraction wound management: medicating postextraction sockets. J Oral Maxillofac Surg. 2000;58(5):531–7. https://doi.org/10.1016/s0278-2391(00)90016-8
12. Hermesch CB, Hilton TJ, Biesbrock AR, Baker RA, Cain-Hamlin J, McClanahan SF, et al. Perioperative use of 0.12% chlorhexidine gluconate for the prevention of alveolar osteitis: efficacy and risk factor analysis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1998;85(4):381–7.
13. Nitzan DW, Sperry JF, Wilkins TD. Fibrinolytic activity of oral anaerobic bacteria. Arch Oral Biol. 1978;23(6):465–70.
14. Nitzan DW. On the genesis of "dry socket". J Oral Maxillofac Surg. 1983;41(11):706–10.
15. Office of National Statistics. 2021. Census Output Area population estimates – North East, England (supporting information). Available at https://www.ons.gov.uk/file?uri=%2fpeoplepopulationandcommunity%2fpopulationandmigration%2fpopulationestimates%2fdatasets%2fcensusoutputareaestimatesinthenortheastregionofengland%2fmid2020sape23dt10d/sape23dt10dmid2020coaunformattedsyoaestimatesnortheast.xlsx (Accessed November 2021)
16. Simpson S, Sumner O, Holiday R, Currie CC, Hind V, Lush N, et al. Paediatric dentistry and the coronavirus (COVID-19) response in the North East of England and North Cumbria. medRxiv. 2020;1:1–16. https://doi.org/10.1101/2020.06.02.20114967
17. Page MJ, McKenzie JE, Bossuyt PM, Hoffmann TC, Mulrow CD, Shamseer L, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71. https://doi.org/10.1136/bmj.n71
18. Nusair YM, Younis MH. Prevalence, clinical picture, and risk factors of dry socket in a Jordanian dental teaching center. J Contemp Dent Pract. 2007;8(3):53–63.
19. Oginni FO, Fatusi OA, Alagbe AO. A clinical evaluation of dry socket in a Nigerian teaching hospital. J Oral Maxillofac Surg. 2003;61(8):871–6.

20. Singh AS, Mohamed A, Bouckaert MM. A clinical evaluation of dry sockets at the Medunsa Oral Health Centre. S Afr Dent J. 2008;63(9):490–3.
21. Bortoluzzi MC, Manfro R, De Déa BE, Dutra TC. Incidence of dry socket, alveolar infection, and postoperative pain following the extraction of erupted teeth. J Contemp Dent Pract. 2010;11(1):E033–40.
22. Simon E, Matee M. Post-extraction complications seen at a referral dental clinic in Dar Es Salaam. Tanzania Int Dent J. 2001;51(4):273–6.
23. Alexander RE. Dental extraction wound management: a case against medicating post-extraction sockets. J Oral Maxillofac Surg. 2000;58(5):538–51.
24. Monaco G, Staffolani C, Gatto MR, Checchi L. Antibiotic therapy in impacted third molar surgery. Eur J Oral Sci. 1999;107(6):437–41.
25. Chiapasco M, Crescentini M, Romanoni G. Estrazione dei terzi molari inferiori: germectomia o avulsione tardiva? Minerva Stomatol. 1994;43(5):191–8. [The extraction of the lower third molars: germectomy or late avulsion?].
26. Field EA, Speechley JA, Rotter E, Scott J. Dry socket incidence compared after a 12-year interval. Br J Oral Maxillofac Surg. 1985;23(6):419–27.
27. Amaratunga NA, Senaratne CM. A clinical study of dry socket in Sri Lanka. Br J Oral Maxillofac Surg. 1988;26(5):410–8.
28. Adeyemo WL, Ladeinde AL, Ogunlewe MO. Clinical evaluation of post-extraction site wound healing. J Contemp Dent Pract. 2006;7(3):40–9.
29. Cohen ME, Simecek JW. Effects of gender-related factors on the incidence of localized alveolar osteitis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1995;79(4):416–22.
30. Bienek DR, Filliben JJ. Risk assessment and sensitivity meta-analysis of alveolar osteitis occurrence in oral contraceptive users. J Am Dent Assoc. 2016;147(6):394–404.
31. Eshghpour M, Dastmalchi P, Nekooei AH, Nejat AH. Effect of platelet-rich fibrin on frequency of alveolar osteitis following mandibular third molar surgery: a double-blinded randomized clinical trial. J Oral Maxillofac Surg. 2014;72(8):1463–7.
32. NHS. 2019. Early or delayed puberty. Online. Available at https://www.nhs.uk/conditions/early-or-delayed-puberty/ (Accessed November 2021)
33. Dance A. Why the sexes don't feel pain the same way. Nature. 2019;567:448–50. https://doi.org/10.1038/d41586-019-00895-3
34. Bartley EJ, Fillingim RB. Sex differences in pain: a brief review of clinical and experimental findings. Br J Anaesth. 2013;111(1):52–8.
35. Chesterton LS, Barlas P, Foster NE, Baxter DG, Wright CC. Gender differences in pressure pain threshold in healthy humans. Pain. 2003;101(3):259–66.
36. Riley JL 3rd, Robinson ME, Wise EA, Myers CD, Fillingim RB. Sex differences in the perception of noxious experimental stimuli: a meta-analysis. Pain. 1998;74(2–3):181–7. https://doi.org/10.1016/s0304-3959(97)00199-1
37. Martin LJ, Acland EL, Cho C, Gandhi W, Chen D, Corley E, et al. Male-specific conditioned pain hypersensitivity in mice and humans. Curr Biol. 2019;29(2):192–201.
38. Thompson AE, Anisimowicz Y, Miedema B, Hogg W, Wodchis WP, Aubrey-Bassler K. The influence of gender and other patient characteristics on health care-seeking behaviour: a QUALICOPC study. BMC Fam Pract. 2016;17:38. https://doi.org/10.1186/s12875-016-0440-0
39. Levitin SA, Jeong IC, Finkelstein J. Mining electronic dental records to identify dry socket risk factors. Stud Health Technol Inform. 2019;262:328–31.
40. al Khateeb TL, el Marsafi AI, Butler NP. The relationship between the indications for the surgical removal of impacted third molars and the incidence of alveolar osteitis. J Oral Maxillofac Surg. 1991;49(2):141–6.
41. Peñarrocha M, Sanchis JM, Sáez U, Gay C, Bagán JV. Oral hygiene and postoperative pain after mandibular third molar surgery. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2001;92(3):260–4.
42. Duangthip D, Chu CH. Challenges in oral hygiene and oral health policy. Front Oral Health. 2020;1:575428. https://doi.org/10.3389/froh.2020.575428
43. MacGregor AJ. Aetiology of dry socket: a clinical investigation. Br J Oral Surg. 1968;6(1):49–58.
44. Sisk AL, Hammer WB, Shelton DW, Joy ED. Complications following removal of impacted third molars: the role of the experience of the surgeon. J Oral Maxillofac Surg. 1986;44(11):855–9.
45. Jerjes W, El-Maaytah M, Swinson B, et al. Experience versus complication rate in third molar surgery. Head Face Med. 2006;2:14. https://doi.org/10.1186/1746-160X-2-14
46. Larsen PE. Alveolar osteitis after surgical removal of impacted mandibular third molars. Identification of the patient at risk. Oral Surg Oral Med Oral Pathol. 1992;73(4):393–7.
47. Septodont. 2019. Alveogyl (Packet Insert). Online Available at https://www.septodont.co.uk/sites/uk/files/2019-03/packInsert-Alveogyl.pdf (Accessed November 2021)
48. Scottish Dental Clinical Effective Programme (SDCEP). Management of acute dental problems - guidelines for clinicians. 2013.
49. Veale B. Alveolar osteitis: a critical review. Oral Surg. 2015;8:68–77.
50. Kalsi H, Major R, Jawad H. Alvogyl or Alveogyl? Br Dent J. 2020;229:211. https://doi.org/10.1038/s41415-020-2073-x
51. Kaya GŞ, Yapici G, Savaş Z, et al. Comparison of alvogyl, SaliCept patch, and low-level laser therapy in the management of alveolar osteitis. J Oral Maxillofac Surg. 2011;69(6):1571–7.
52. Septodont. 2020. Alveogyl (Packet Insert). Online. Available at https://www.septodont.co.uk/sites/uk/files/2020-06/S05940470300-alveogyl.pdf (Accessed November 2021)
53. Krastl G, Allgayer N, Lenherr P, Filippi A, Taneja P, Weiger R. Tooth discoloration induced by endodontic materials: a literature review. Dent Traumatol. 2012;29(1):2–7.
54. Forestier-Zhang L, Bishop N. Bone strength in children: understanding basic bone biomechanics. Arch Dis Child Educ Pract Ed. 2016;101(1):2–7.
55. Marenzana M, Arnett TR. The key role of the blood supply to bone. Bone Res. 2013;1(3):203–15.
56. Health & Social Care Information Centre. Children's Dental Health Survey 2013. Available at https://files.digital.nhs.uk/publicationimport/pub17xxx/pub17137/cdhs2013-report1-attitudes-and-behaviours.pdf (Accessed November 2021)
57. Wu L, Gao X. Children's dental fear and anxiety: exploring family related factors. BMC Oral Health. 2018;18:100. https://doi.org/10.1186/s12903-018-0553-z
58. Riley RD, Snell KI, Ensor J, Burke DL, Harrell FE Jr, Moons KG, et al. Minimum sample size for developing a multivariable prediction model: PART II-binary and time-to-event outcomes. Stat Med. 2019;38(7):1276–96.
59. Khan BT, Kiani MN, Saeed MH, Khan AZ. Risk factors assessment for dry sockets: A logistic regression analysis study. J Oral Maxillofac Surg Med Pathol. 2015;27(6):753–6.

How to cite this article: Donnell CC, Clark MV, Corbett IP. Do children get dry socket?—The incidence and pattern of presentation of alveolar osteitis in children and adolescents following dental extractions. Oral Surg. 2022;00:1–10. https://doi.org/10.1111/ors.12755