

The development and application of a chairside oral health risk and need stratification tool in general dental services

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ABSTRACT

Objective: To describe the development and application of the Assessment of Clinical Oral Risks and Needs (ACORN) stratification tool based on a traffic light system in National Health Service (NHS) general dental services (GDS) Wales, UK.

Materials and methods: This was a secondary analysis of routinely-collected dental care data. All courses of treatment provided in dental practices participating in NHS GDS Reform Programme between July 2018 and September 2019, in which an ACORN assessment and age were recorded were included in the analysis.

Results: A total of 236,490 subjects contributed 339,933 courses of treatment during the study period. 'Amber' and 'red' ACORN outcomes were associated with more courses of treatment per annum than 'green' outcomes. Outcomes indicating an increased risk of decay or other dental problems were associated with a greater likelihood of several operative treatment items. Patients at greater risk of poor periodontal health were more likely to receive extractions and dentures than low-risk patients. Patients were most likely to either remain in the same ACORN outcome categories or move to a healthier state between assessments.

Conclusion: More research is required to understand the utility of the ACORN tool in risk communication and behaviour change.

1. Background

Risk stratification is increasingly being used in clinical care to inform resource allocation, case prioritisation and facilitate the appropriate delivery of preventive interventions [1]. Although risk stratification has a long history in private health care systems in the United States, its use in European public health care remains at a comparatively early stage [2].

The outcomes of risk stratification can be presented in a number of ways: predictive risk scores (on continuous or ordinal scales); primary care management costs; or likelihood of adverse outcome(s) [2]. The categorisation and presentation of risk using a 'traffic light' system provides a model that can be used to synthesise complex clinical data into an aggregate risk score and has been adopted in varying forms across paediatrics, cardiovascular disease and haematology [3–5]. In

such systems, red typically infers high risk; amber, medium risk; and green, low risk.

Traffic light risk stratification has, in recent years, also found an application in primary dental care. The National Health Service (NHS) dental contract reform prototypes in England, UK used a preventive care pathway informed by a standardised assessment to gather information on and to assign risk in four clinical areas: dental caries, periodontal disease, tooth surface loss and soft tissue conditions [6]. Risk was determined based on both patient and clinical factors and an associated self-care plan provided patient-specific information using a red, amber, and green system. The risk rating also informed the recall interval and any preventive visits.

Whilst a recent trial in NHS dental care in England reported that patients at medium to high risk of poor oral health preferred verbal advice to being classified in a traffic light system [7], risk stratification

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tools based on such systems may still have utility for the identification of individuals most in need of care and to inform contracting models in dental care. This paper therefore describes the development and application of the chairside Assessment of Clinical Oral Risks and Needs (ACORN) stratification tool based on a traffic light system in general dental services (GDS) Wales, UK.

2. Methods

2.1. Design

This was a secondary analysis of routinely-collected data on dental care delivery.

2.2. Setting

NHS GDS are the principal providers of primary dental care in Wales, UK. This is a state-subsidised system of care in which dental practices are independent contractors of Local Health Boards (LHBs). LHBs are the organisations responsible for planning and delivering NHS services across a specified geographical area.

The setting for this study were practices participating in the NHS Wales GDS Reform Programme ($n = 82$) between July 2018 and September 2019. The NHS Wales General Dental Service Reform Programme was established in 2017 to explore new contracting models for NHS dental care in Wales [8]. One of the objectives of the programme is to 'ensure dental services undertake an assessment of the oral health risks and needs of individual patients once a year using a standardised toolkit' [9].

2.3. Development of the ACORN tool

The ACORN tool was developed through an iterative, participatory approach in which the people in charge of solving a problem or designing an innovation (in this case the NHS Wales GDS Reform Programme Team in Public Health Wales) involve people who are directly concerned by the result of their work (in this case dental teams) [10].

The prototype was developed during two workshops for dental professionals (January and May 2017) and feedback provided by a multistakeholder steering group (September 2017). The ACORN acronym was suggested by a general dental practitioner. Between September and December 2017, 21 GDS practices across seven LHBs tested the revised toolkit and provided further feedback to the steering group. The ACORN toolkit, which was launched in January 2018, is presented in the Supplementary Information to this manuscript.

The resultant product was a paper-based risk-stratification instrument (see Supplementary Information) that collects information on:

- Inherent patient risks from medical, social and dental history
- Key modifiable risk behaviours and protective factors relevant to the development of dental caries and periodontal diseases
- Clinical findings including: dental caries; Basic Periodontal Examination (BPE); bleeding on probing; periodontal pocket depths; soft tissue pathologies; presence of intraoral appliances; plaque levels; and other conditions such as tooth surface loss, trauma, or failing restorative treatment

The principal outcomes which are recorded by ACORN are:

- Medical history which impacts on oral health and/or dental care planning (graded as 'yellow' for the presence of relevant factors; 'green' for the absence of relevant factors)
- Social history which impacts on oral health and/or dental care planning (graded as 'yellow' for the presence of relevant factors; 'green' for the absence of relevant factors)

- Dental history which impacts on oral health and/or dental care planning (graded as 'yellow' for the presence of relevant factors; 'green' for the absence of relevant factors)
- Tooth decay ('red' indicating active caries into dentine or beyond; 'amber' indicating active enamel caries only OR the presence of key modifiable risk factors for tooth decay; 'green' indicating no active caries and no modifiable risk factors for tooth decay)
- Periodontal health ('red' indicating BPE scores of 3 or more in any sextant and bleeding on probing; 'amber' indicating BPE scores of 3 or more in any sextant but no bleeding on probing OR presence of key modifiable risk factors for periodontitis; 'green' indicating BPE scores of 2 or lower in all sextants and no presence of key modifiable risk factors)
- Other dental need ('red' indicating the presence of other conditions/pathologies/failing restorations NOT caries or periodontal diseases that require active intervention; 'amber' indicating the presence of other conditions/pathologies/failing restorations NOT caries or periodontal diseases that require active monitoring but no intervention; 'green' the absence of other conditions/pathologies/failing restorations NOT caries or periodontal diseases)
- Total number of teeth
- Number of deciduous teeth with dentinal decay
- Number of permanent teeth with dentinal decay

2.4. Data source

All NHS general dental practices in Wales submit information on the items of dental care completed under each course of treatment provided under an NHS GDS or Personal Dental Services (PDS) contract on a FP17W form to the NHS Business Services Authority (NHS BSA). In addition from July 2018, practices participating in the NHS Wales GDS Reform Programme submitted the ACORN toolkit outcomes via the FP17W on an annual basis.

2.5. Case selection

All courses of treatment provided in NHS Wales GDS Reform Programme Practices between 1st July 2018 – 30th September 2019 to NHS patients with a recorded ACORN assessment and age (at the date of treatment acceptance) were included in the dataset. As practices joined the GDS Reform Programme at different stages during the study period, the index date was the later of the date the practice joined the GDS reform programme and the study start date. Patients were followed until the end of the study period.

The following anonymised data were extracted per course of treatment:

- Provider information (name; city/town; postcode)
- Patient information (anonymised patient identifier; city/town; postcode; age [at date on which the course of treatment was opened])
- Incomplete treatment [if applicable]
- Course of treatment dates (date of acceptance [commencement of course of treatment]; date of completion)
- Treatment category (NHS treatment band under NHS Wales GDS Regulations (2006); regulation 11 replacement appliance; prescription only; denture repairs; bridge repairs; arrest of bleeding; removal of sutures)
- Clinical data set (scale and polish; fluoride varnish, fissure sealants, radiographs; endodontic treatment; permanent fillings and sealant restorations; extractions; crowns; upper denture – acrylic; lower

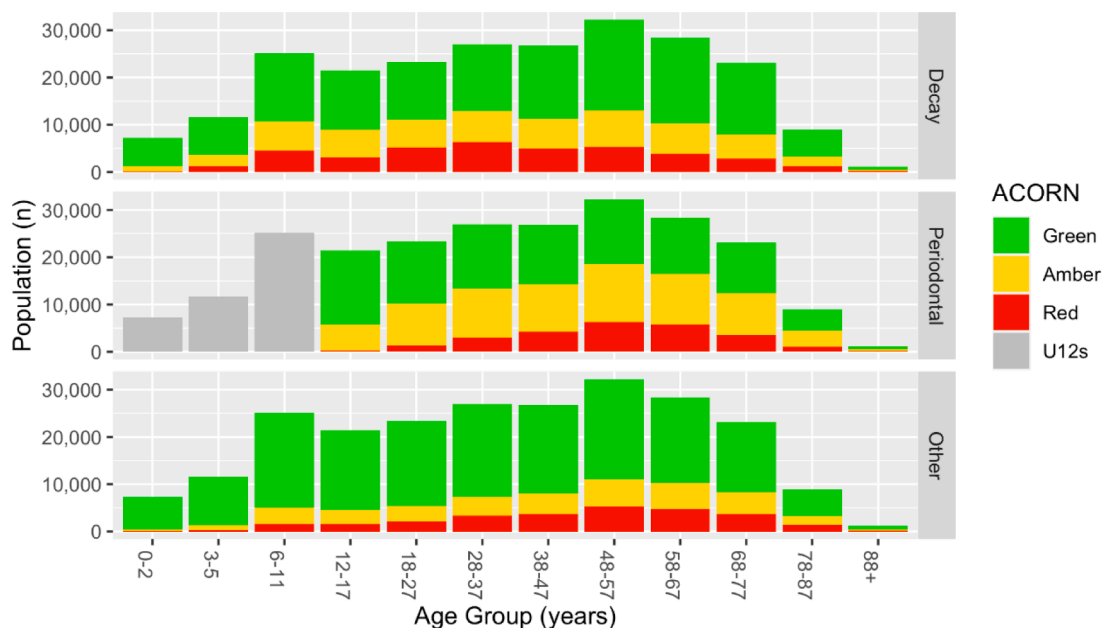


Fig. 1. Distribution of study population (n = 236,490) by age and ACORN outcome.

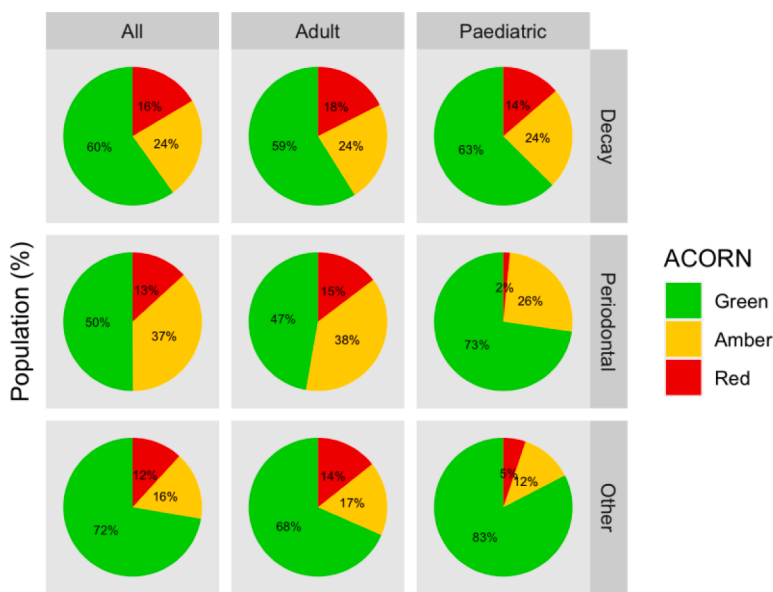


Fig. 2. Distribution of study population by adult/paediatric status and ACORN outcome.

denture – acrylic; upper denture – metal; lower denture – metal; veneers; inlays; bridges; referral for advanced mandatory services; examination; antibiotic items prescribed; other treatment; best practice prevention according to Delivering Better Oral Health offered¹

- ACORN outcomes (risk from medical history; risk from social history, risk from dental history; tooth decay; periodontal health; other dental need)
- Other services (treatment on referral; free repair/replacement; further treatment within 2 months; domiciliary services; sedation services)

- National Institute of Clinical Excellence (NICE) recommended recall interval [number of months]

2.6. Analysis

Data were analysed to build up pathways of current patient care in NHS Wales GDS Reform Programme Practices and probabilities associated with the likely delivery of clinical treatment items.

The independent variables of interest were number of courses of treatment per year and frequency of treatment item delivery.

The dependant variables of interest were ACORN tool outcomes (tooth decay need and risk [‘red’, ‘amber’, or ‘green’]; periodontal need and risk [‘red’, ‘amber’, or ‘green’], and other dental need [‘red’, ‘amber’, or ‘green’]).

Courses of treatment per annum was calculated per patient by dividing the number of FP17Ws attributable to a single patient by the

¹ Some treatment items are defined in terms of the number teeth treated, while others are defined in terms of number of treatment courses (or more specifically the number of FP17W forms submitted).

Table 1
Patient and practice factors and mean courses of treatment (COT) per annum.

	Total (n = 236,490)	Mean COT per annum (95% CI)
Patient factors		
Age		
0–17 years	65,515	1.67 (1.67, 1.68)
18–27 years	23,330	1.57 (1.56, 1.58)
28–37 years	26,985	1.62 (1.61, 1.63)
38–47 years	26,813	1.68 (1.67, 1.69)
48–57 years	32,232	1.77 (1.76, 1.77)
58–67 years	28,363	1.85 (1.84, 1.86)
68–77 years	23,136	1.86 (1.85, 1.87)
78–87 years	8946	1.80 (1.79, 1.82)
>=88 years	1170	1.77 (1.72, 1.81)
Welsh Index of Multiple Deprivation		
Rank 1–382 (most deprived)	48,382	1.76 (1.75, 1.77)
Rank 383–764	49,029	1.74 (1.73, 1.74)
Rank 765–1146	46,571	1.69 (1.68, 1.69)
Rank 1147–1528	44,297	1.69 (1.69, 1.71)
Rank 1529–1909 (least deprived)	48,211	1.70 (1.69, 1.71)
Tooth decay RAG outcome		
Green	141,716	1.73 (1.72, 1.73)
Amber	55,785	1.68 (1.68, 1.70)
Red	38,989	1.72 (1.71, 1.73)
Periodontal health RAG outcome		
Green	96,360	1.69 (1.69, 1.70)
Amber	70,647	1.69 (1.68, 1.70)
Red	25,442	1.92 (1.91, 1.94)
N/A (<=12 years)	44,041	1.69 (1.69, 1.70)
Other dental health outcome		
Green	171,079	1.68 (1.67, 1.68)
Amber	37,507	1.85 (1.84, 1.85)
Red	27,904	1.78 (1.77, 1.79)
Practice factors		
Local Health Board		
Aneurin Bevan University Health Board	48,344	1.72 (1.72, 1.73)
Betsi Cadwaladr University Health Board	32,363	1.55 (1.55, 1.56)
Cardiff and Vale University Health Board	45,159	1.80 (1.79, 1.80)
Cwm Taf Morgannwg University Health Board	46,529	1.93 (1.92, 1.93)
Hywel Dda University Health Board	18,855	1.67 (1.66, 1.68)
Powys Teaching Health Board	7111	1.69 (1.67, 1.71)
Swansea Bay University Health Board	38,129	1.52 (1.52, 1.53)

number of days the practice was contributing ACORN data to NHS BSA. To identify factors associated with number of courses of treatment per annum, a two-level random intercept regression model was fitted. Explanatory variables were selected on the basis of scientific literature and the clinical experience of the study team.

Frequency of delivery of the most common treatment items were calculated by dividing the number of FP17Ws in which a treatment item was included by total courses of treatment per ACORN outcome strata. Treatment items reported by number of teeth treated were dichotomised, in which ‘0’ represented ‘not delivered during the course of treatment’ and ‘1’ represented ‘one or more delivered during the course of treatment’. Frequencies of eleven of the most common treatment items are presented herein. Similar treatment items were grouped together for ease of interpretation (such as the four treatment items relating to the provision of removable prostheses or dentures). To explore the association between frequency of treatment item delivery and ACORN outcomes three-level random intercept logistic regression models were fitted. Potential confounders of patient age and socioeconomic deprivation were controlled for in these models.

The probability of transitioning between different ACORN outcomes (e.g. movement from ‘red’ to ‘amber’ within a particular domain) was calculated for all individuals who had two FP17Ws containing ACORN

Table 2
Two-level regression model of courses of treatment per annum.

	Co-efficient (β)	SE
Patient factors		
Age		
0–17 years	Reference group	
18–27 years	–0.092***	0.006
28–37 years	–0.041***	0.006
38–47 years	–0.003	0.006
48–57 years	0.068***	0.006
58–67 years	0.143***	0.006
68–77 years	0.153***	0.006
78–87 years	0.111***	0.008
>=88 years	0.039*	0.020
Welsh Index of Multiple Deprivation		
Rank 1–382 (most deprived)	Reference group	
Rank 383–764	–0.010**	0.004
Rank 765–1146	–0.011*	0.005
Rank 1147–1528	–0.007	0.005
Rank 1529–1909 (least deprived)	–0.001	0.005
Tooth decay RAG outcome		
Green	Reference group	
Amber	0.023***	0.004
Red	0.029***	0.004
Periodontal health RAG outcome		
Green	Reference group	
Amber	0.012**	0.004
Red	0.181***	0.005
N/A (<=12 years)	0.056***	0.006
Other dental health outcome		
Green	Reference group	
Amber	0.069***	0.004
Red	0.025***	0.005
Practice factors		
Local Health Board		
Aneurin Bevan University Health Board	–0.061***	0.010
Betsi Cadwaladr University Health Board	–0.300	0.182
Cardiff and Vale University Health Board	Reference group	
Cwm Taf Morgannwg University Health Board	–0.372*	0.124
Hywel Dda University Health Board	0.834***	0.129
Powys Teaching Health Board	0.053	0.242
Swansea Bay University Health Board	0.136	0.124
Intercept	1.731	0.090

SE standard error; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. Individual $n = 236,490$; practice $n = 82$.

tool outcomes within the 15-month data extraction window. As patients under 12 years of age do not receive an ACORN outcome for the periodontal health domain, transition probabilities were calculated separately for subjects aged <12 years and those aged ≥12 years. In order to simplify the number of transitional probabilities, the other dental need domain was dichotomised into a ‘red’ and ‘non-red’ (i.e. ‘amber’ and ‘green’) outcomes.

Analyses were undertaken using R and STATA. Multilevel regression models were constructed using MLwiN.

2.7. Ethics

The study was reviewed and given a favourable opinion by Wales Research Ethics Committee 7 (20/WA/0081). The processing of pseudo-anonymised patient data held by NHS BSA in the absence of individual consent was undertaken under Regulation 5 of the Health Service (Control of Patient Information) Regulations 2002 (‘section 251 support’). This processing was approved by the Confidentiality Advisory Group of the Health Research Authority (20/CAG/0131).

3. Results

A total of 236,490 subjects were eligible for inclusion in the analyses. These contributed a total of 339,933 courses of treatment during the study period. Individuals were followed from their index date for an

Table 3
Frequency of common treatment items per 100 courses of treatment (COT).

Treatment item	Total frequency per 100 COT (95% CI)	Frequency per ACORN tooth decay outcome per 100 COT (95% CI)			Frequency per ACORN periodontal health outcome per 100 COT (95% CI)			Frequency per ACORN other dental need outcome per 100 COT (95% CI)			
		Green	Amber	Red	Green	Amber	Red	NA (<12 years)	Green	Amber	Red
Examination (routine)	95.52 (95.45, 95.59)	95.94 (95.85, 96.02)	95.65 (95.50, 95.78)	93.80 (93.59, 93.99)	95.18 (95.06, 95.29)	95.03 (94.90, 95.17)	94.86 (94.64, 95.08)	97.48 (97.36, 97.61)	96.21 (96.13, 96.29)	94.33 (94.14, 94.52)	93.05 (92.80, 93.29)
Fluoride varnish	27.08 (26.92, 27.23)	23.42 (23.23, 23.60)	29.54 (29.23, 29.85)	36.82 (36.42, 37.22)	20.18 (19.97, 20.40)	18.92 (18.67, 19.16)	18.16 (17.78, 18.54)	61.02 (60.64, 61.41)	27.26 (27.09, 27.44)	28.87 (28.50, 29.25)	23.51 (23.10, 23.93)
Scale & polish	26.85 (26.70, 26.99)	24.53 (24.34, 24.71)	27.36 (27.06, 27.67)	34.58 (34.18, 34.97)	22.54 (22.32, 22.76)	36.43 (36.13, 36.72)	54.72 (54.23, 55.20)	3.00 (2.87, 3.14)	25.71 (25.54, 25.89)	26.66 (26.29, 27.03)	33.84 (33.38, 34.30)
Best practice prevention	23.08 (22.94, 23.53)	22.40 (22.22, 22.58)	23.59 (23.30, 23.88)	24.84 (24.48, 25.20)	22.00 (22.22, 22.22)	23.06 (21.78, 23.32)	25.68 (25.25, 26.11)	23.84 (23.50, 24.17)	22.72 (22.55, 22.89)	21.82 (21.48, 22.17)	26.97 (26.54, 27.40)
Radiograph(s)	21.63 (21.49, 21.76)	17.52 (17.35, 17.69)	20.42 (20.14, 20.69)	38.51 (38.10, 38.91)	24.34 (24.11, 24.56)	27.17 (26.90, 27.44)	28.28 (28.01, 28.90)	2.40 (2.28, 2.52)	19.69 (19.53, 19.85)	22.11 (21.76, 22.45)	32.51 (32.05, 32.96)
Permanent filling(s) & sealant restoration(s)	19.60 (19.47, 19.73)	9.72 (9.59, 9.85)	15.21 (15.96, 15.46)	62.40 (61.99, 62.80)	19.74 (19.53, 19.95)	22.64 (22.38, 22.90)	21.56 (21.16, 21.97)	13.13 (12.86, 13.39)	15.33 (15.19, 15.48)	18.34 (18.02, 18.66)	46.74 (46.25, 47.22)
Extraction(s)	5.03 (4.96, 5.11)	3.10 (3.02, 3.17)	4.03 (3.90, 4.17)	13.62 (13.34, 13.91)	3.73 (3.63, 3.84)	5.61 (5.47, 5.75)	12.69 (12.40, 13.01)	2.06 (1.95, 2.17)	3.31 (3.24, 3.38)	4.44 (4.27, 4.61)	16.12 (15.77, 16.48)
Examination (urgent)	4.48 (4.41, 4.55)	4.06 (3.98, 4.15)	4.35 (4.22, 4.50)	6.20 (6.01, 6.41)	4.82 (4.71, 4.94)	4.97 (4.83, 5.10)	5.14 (4.95, 5.36)	2.52 (2.39, 2.64)	3.79 (3.71, 3.87)	5.67 (5.48, 5.86)	6.95 (6.71, 7.20)
Denture(s)	1.82 (1.77, 1.86)	1.50 (1.45, 1.56)	1.63 (1.55, 1.72)	3.24 (3.10, 3.39)	1.53 (1.46, 1.59)	2.09 (2.08, 2.18)	4.98 (4.76, 5.19)	0.00 (0.00, 0.00)	0.78 (0.74, 0.81)	1.53 (1.43, 1.64)	8.49 (8.12, 8.65)
Crown(s) and bridge(s)	1.60 (1.55, 1.64)	1.26 (1.21, 1.31)	1.40 (1.32, 1.48)	3.12 (2.97, 3.26)	1.88 (1.81, 1.95)	2.08 (1.99, 2.17)	1.87 (1.74, 2.00)	0.03 (0.01, 0.04)	0.80 (0.76, 0.83)	1.43 (1.33, 1.53)	6.58 (6.34, 6.82)
Endodontic treatment(s)	0.93 (0.91, 0.97)	0.56 (0.53, 0.59)	0.73 (0.67, 0.79)	2.60 (2.47, 2.74)	1.11 (1.06, 1.17)	1.21 (1.14, 1.28)	1.01 (0.91, 1.11)	0.04 (0.03, 0.06)	0.56 (0.53, 0.59)	0.84 (0.77, 0.92)	3.30 (3.12, 3.47)

average of 47 (median 52) weeks, representing a total follow-up period of 211,796 years. Subject age followed a bio-modal distribution with peaks at 6–11 and 48–57 years of age (Fig. 1).

In all three ACORN tool outcome domains (tooth decay, periodontal health and other dental need), subjects were most likely to be assessed as ‘green’, followed by ‘amber’ and finally ‘red’ (Fig. 2). Whilst the proportions of individuals with ‘red’/‘amber’/‘green’ scores was similar in adult and paediatric (defined as individuals ≤ 17 years of age) populations for the tooth decay domain of ACORN, larger proportions of paediatric subjects had ‘green’ and ‘amber’ outcomes for the periodontal health and other dental need domain compared to adults.

Individuals received on average 1.71 courses of treatment per annum (95% CI 1.71, 1.72). The majority of subjects (66%) had a single course of treatment during the 15-month study period, 27% had two courses, and 7% of individuals had three or more courses of treatment. Once patient age, deprivation and practice location were controlled for in multilevel linear models, outcomes of ‘amber’ or ‘red’ were associated with statistically significant higher courses of treatment per annum than ‘green’ outcomes across all three ACORN outcome domains (Tables 1 and 2). Individuals with ‘red’ outcome for the periodontal health domain received on average the most courses of treatment per annum once potential confounding factors were controlled for.

The frequency of treatment items per 100 courses of treatment is presented in Table 3. Routine examination was the most frequent treatment item (95.5 per 100 courses of treatment). Urgent examinations were significantly more common in ‘amber’ and ‘red’ tooth decay and other dental need domains than ‘green’, after controlling for patient age and socioeconomic status. This suggests patients at a greater risk of dental caries and other dental problems are more likely to present requiring urgent care (Table 4). However a reverse pattern was seen

with periodontal outcomes where there was a greater likelihood of routine consultations for patient with ‘amber’ and ‘red’ outcomes than those with ‘green’ periodontal outcomes. This potentially indicates a more regular pattern of dental visiting amongst patients with periodontal disease.

Within the tooth decay domain, the frequency of most treatment items was higher for patients with ‘amber’ or ‘red’ outcomes compared to those with a ‘green’ outcome. The only exception to this was ‘amber’ outcomes for dentures where the difference was non-significant (Table 4).

Scale and polish, extractions and dentures were more likely to occur in consultations with patients with an ‘amber’ or ‘red’ periodontal health outcome than those with a ‘green’ outcome (Table 4). However, best-practice prevention, permanent filling and sealant restorations, crowns and bridges and endodontic treatment were all less likely in patients with periodontal disease (‘amber’ or ‘red’ outcomes) than those without (‘green’ outcome).

The frequency of most treatment items was higher in patients with an ‘amber’ or ‘red’ outcome for other dental need than patients with a ‘green’ outcome, with the exception of scale and polish, routine examination and best practice prevention (‘amber’ only) (Table 4).

To calculate the probability of transitioning between ACORN outcome states within domains, a subset of 33,402 eligible subjects were identified (6575 patients <12 years of age and 26,861 patients aged 12 years and over). These individuals contributed a total of 83,278 courses of treatment during the study period, were followed from their index date for an average of 59 (median 65) weeks, and represented a total follow-up period of 37,617 years.

When considering the subgroup of patients with two ACORN assessments, individuals <12 years of age were most likely to either

Table 4
Three-level regression model of common treatment item frequency.

Treatment items	Intercept	SE	ACORN outcomes				Periodontal health				NA(≤12 years)		Other dental need						
			Tooth decay		Red		Green		Amber		Red		Green		Amber		Red		
			Green	Amber	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	
Examination (routine)	4.24	0.10	Reference group	0.86***	0.82, 0.90	0.68***	0.65, 0.71	Reference group	1.05*	1.00, 1.10	1.18***	1.11, 1.25	0.72***	0.65, 0.80	Reference group	0.71***	0.67, 0.74	0.60***	0.57, 0.63
Fluoride varnish	-0.13	0.17		1.54***	1.50, 1.58	2.31***	2.26, 2.37		1.01	0.98, 1.04	1.10***	1.07, 1.14	1.13***	1.09, 1.16		1.23***	1.20, 1.26	1.14***	1.11, 1.18
Scale & polish	-2.16	0.15		1.05***	1.03, 1.07	1.23***	1.21, 1.26		2.02***	1.98, 2.06	3.11***	3.03, 3.19	0.25***	0.23, 0.26		0.86***	0.84, 0.88	0.94***	0.92, 0.97
Best practice prevention	-0.88	0.34		1.13***	1.11, 1.16	1.05***	1.03, 1.08		0.97**	0.95, 0.99	0.96***	0.93, 0.98	1.02	0.99, 1.05		0.95***	0.93, 0.97	1.07***	1.04, 1.09
Radiograph(s)	-1.76	0.11		1.22***	1.19, 1.25	2.57***	2.51, 2.63		1.00	0.97, 1.02	0.98	0.96, 1.01	0.10***	0.10, 0.11		1.12***	1.09, 1.15	1.40***	1.37, 1.44
Permanent filling(s) & sealant restoration(s)	-2.66	0.05		1.96***	1.91, 2.02	16.71***	16.29, 17.14		0.84***	0.82, 0.86	0.52***	0.50, 0.54	0.73***	0.70, 0.77		1.27***	1.23, 1.31	4.15***	4.03, 4.27
Extraction(s)	-3.74	0.09		1.25***	1.19, 1.30	3.73***	3.59, 3.88		1.32***	1.27, 1.38	2.70***	2.58, 2.82	0.47***	0.44, 0.51		1.38***	1.31, 1.44	3.95***	3.80, 4.10
Examination (urgent)	-4.24	0.10		1.16***	1.11, 1.22	1.48***	1.41, 1.55		0.96*	0.91, 1.00	0.85***	0.80, 0.90	1.39***	1.25, 1.55		1.41***	1.34, 1.48	1.66***	1.57, 1.74
Denture(s)	-8.02	0.28		1.04	0.97, 1.11	1.38***	1.30, 1.47		1.09**	1.03, 1.16	1.75***	1.63, 1.87	0.04***	0.01, 0.25		1.71***	1.58, 1.85	8.26***	7.79, 8.77
Crown(s) and bridge(s)	-6.54	0.17		1.20***	1.11, 1.29	1.87***	1.75, 1.99		0.87***	0.82, 0.93	0.52***	0.48, 0.57	0.13***	0.08, 0.22		1.56***	1.43, 1.70	6.37***	5.98, 6.78
Endodontic treatment(s)	-6.17	0.14		1.39***	1.25, 1.54	3.49***	3.20, 3.80		0.87**	0.81, 0.95	0.54***	0.48, 0.61	0.13***	0.08, 0.19		1.51***	1.35, 1.68	4.44***	4.09, 4.82

Consultation $n = 339,933$; patient $n = 236,490$; practice $n = 82$. Model controls for patient age and socioeconomic status. B co-efficient; OR odds ratio; 95% CI 95% confidence interval; SE standard error; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

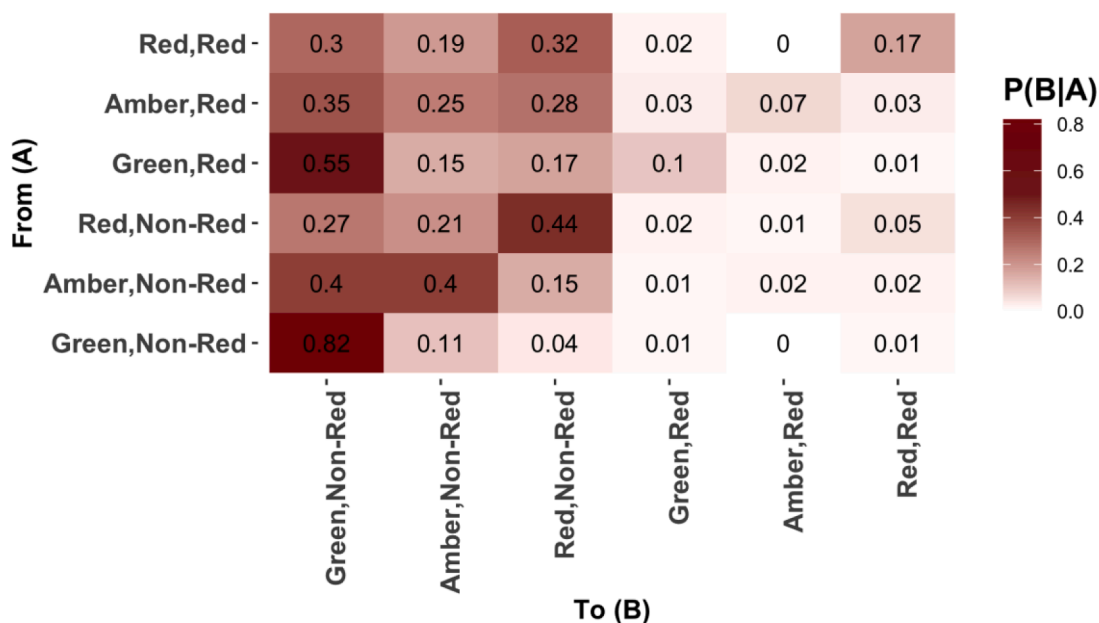


Fig. 3. Probability of transitioning between ACORN outcome states (tooth decay and other dental need) for individuals aged <12 years of age (n = 6575).

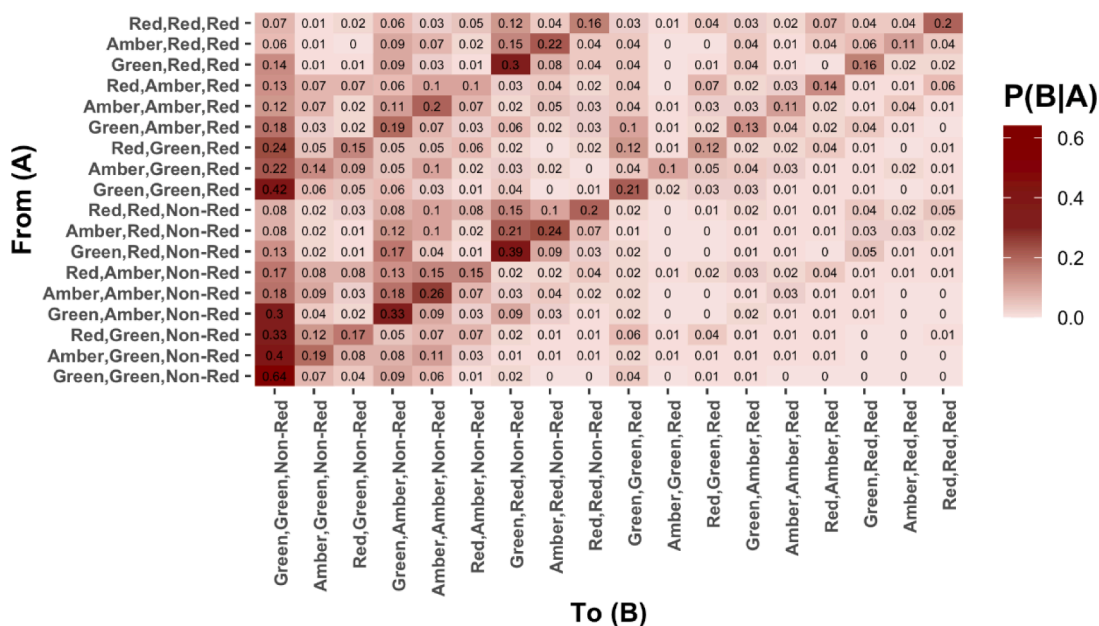


Fig. 4. Probabilities of transitioning between ACORN outcome states (tooth decay, periodontal health, other dental need) for individuals aged ≥12 years of age (n = 26,861).

remain in the same ACORN outcomes at their second assessment (indicated in Fig. 3 by a dark diagonal line running from south-west to north-east) or improve (indicated in Fig. 3 by a cluster of darker squares in the north-west corner of the matrix). amongst individuals ≥12 years of age, there were ten ACORN outcome combinations that were most likely to demonstrate improvement by the second ACORN. For seven out of these ten the improvement was, solely or partly attributable to a change in the other dental need outcome from ‘red’ to ‘non-red’ (indicated on Fig. 4 by a darker diagonal line running west to north). The remaining eight ACORN outcome combinations were most likely to remain the same at the second ACORN (indicated in Fig. 4 by a dark diagonal line running from south-west to north-east).

4. Discussion

This paper describes the development and application of the ACORN chairside oral health risk and need stratification tool in general dental services Wales, UK and the characteristics of consultations associated with different ACORN outcomes. ‘Amber’ and ‘red’ ACORN outcomes were associated with more courses of treatment per annum than ‘green’ outcomes. Urgent examinations were significantly more common in patients at increased risk of dental caries or other dental problems than patients with ‘green’ outcomes for these domains after controlling for patient age and socioeconomic status but the opposite was observed in periodontal health outcomes. The frequency of most items of treatment was higher in patients classified as higher-risk of tooth decay and other dental problems (‘amber’ or ‘red’ outcomes) than low risk (‘green’)

patients. However, the patients at greater risk of periodontal disease ('amber' or 'red' outcomes) were less likely to receive permanent restorations, crowns and bridges and endodontic treatment, and more likely to receive extractions and dentures than low-risk patients, potentially reflecting a more compromised dentition.

The first iteration of the ACORN toolkit was used by early entrants to the NHS Wales GDS Reform Programme in September 2017. There have been minor amendments in the periodontal health section of the toolkit since this study. Although the reform programme was paused at the start of the pandemic, all NHS practices in Wales were asked to use the ACORN toolkit during the pandemic. At the time of writing (May 2022), the reform programme has restarted and it is a mandatory requirement for all practices in the reform programme to provide annual oral health and risk assessment using the ACORN toolkit to all regularly attending patients. The data included in this analysis therefore represents that collected towards the beginning of its implementation. Although validation of ACORN is beyond the scope of this paper, it appears that ACORN outcomes are associated with both the frequency of dental care and the provision of items of care. However, since practitioners have received relatively little training into its use, and no calibration was undertaken, it is unclear how much intra- and inter-practitioner and intra- and inter-practice variation exists. There was no incentive attached to risk stratification and thus the likelihood of risks categories being manipulated for financial or other gain was absent during the study period. This could be important to consider if, in the future, remuneration is linked to practice risk and need profile.

In the current dataset approximately one in seven patients had two or more ACORN assessments within the 15 month period. The two most common outcomes of the second assessment was either no change or an improvement in one or more ACORN outcomes. However, it is premature to speculate whether this is a result of improvements in oral health as a result of health-related behaviour advice provided during the previous course of treatment or a result of underlying changes in how practitioners completed ACORNs during the data collection period.

Changes to the ACORN tool in October 2019 to reflect the implementation of the 2017 Classification of Periodontal Diseases meant that it was not appropriate to combine ACORN assessments from before and after this date in a single analysis. Similarly, although the changes to the periodontal health domain of ACORN due to the new classification system were relatively minor, without further analyses it is not possible to generalise findings from the analysis presented here to that arising from the current iteration of ACORN.

The ACORN toolkit was primarily developed with the aim of facilitating personalised clinical risk assessment, communication and integration of a preventive approach in dental care planning within NHS general dental services. However, further work is required to explore whether ACORN effectively facilitates risk communication in dental settings, particularly considering previous research on the limitations of traffic light-based systems in this respect [7]. Whilst it may be the aim of policymakers to encourage explicit, personalised discussions about health-related behaviours, an ethnographic study of NHS dental practices has revealed that discussions about risk in dentistry are often implicit, defensive and focused on social interaction [11]. Further research is therefore required to explore how the ACORN tool is used by dental practitioners as part of the discussion about personal risks, dental care planning and delivery. More importantly research is also needed to understand how patients receive such personalised risk communication and if they change their risk behaviours.

5. Conclusion

ACORN is a chairside oral health risk and need stratification tool which has been developed via a participatory approach for use in NHS general dental services in Wales, UK. ACORN outcomes appear to be correlated with consultation frequency and the frequency of delivery of

treatment items. Data collected from early adopters of the ACORN demonstrates that patients are most likely to either remain in the same ACORN outcome categories or move to a healthier state between assessments, although the mechanism underlying this remains unknown. More research is required to understand the role of this tool in delivery of patient-centred preventive dental care and behaviour change in dental settings.

6. Clinical significance

This work describes an oral health risk and needs stratification tool and demonstrates its use in general dental practice. It suggests such a tool can be used in a practical setting to direct dental care.

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CRedit authorship contribution statement

Anwen Louise Cope: Conceptualization, Writing – original draft, Funding acquisition. **Christian Bannister:** Methodology, Data curation, Formal analysis. **Anup Karki:** Methodology, Writing – review & editing. **Paul Harper:** Methodology. **Michael Allen:** Methodology, Writing – review & editing. **Rhiannon Jones:** Project administration. **Sarah Peddle:** Public and patient representation. **Brenda Walters:** Public and patient representation. **Ivor Gordon Chestnutt:** supervision, writing review and editing, funding acquisition.

Declaration of Competing Interest

The authors have no conflict of interest to declare.

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