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Draining infections and draining resources:

The nature and cost of acute odontogenic infection referrals to the Oral and Maxillofacial Surgical Service at Christchurch Hospital

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Abstract

Background and objectives: The management of preventable acute odontogenic infections accounts for a large volume of the workload for oral and maxillofacial surgical (OMS) services in public hospitals. This draws valuable public resources away from other high-need patient groups requiring OMS input, such as those with pathology or facial trauma. This study aimed to quantify the number of patients with acute odontogenic infections referred to the Christchurch Hospital OMS service from 1st January 2018 to 31st December 2020, paying particular attention to the ethnic make-up. Additionally, it sought to examine the level of care required by patients, and the financial cost attributable to their management.

Methods: We conducted an audit of clinical records of all patients with odontogenic infections referred to the OMS service at Christchurch Hospital during the aforementioned period.

Results: In total, 900 patients with acute odontogenic infections were referred. The rate of patient referrals per 1,000 of the general Canterbury region population doubled during the three-year study period from 0.32 in 2018 to 0.63 in 2020 (rate ratio = 2.01, 95% CI [1.69, 2.40]). The age-standardised rate ratio of referrals for Māori to NZ Europeans was 3.60, 95% CI [3.04, 4.26], and for Pacific peoples to NZ Europeans was 2.83, 95% CI [2.11, 3.73]. Of those referred, Māori were significantly more likely than NZ Europeans to initially present to the Emergency Department rather than be referred by primary care services such as general dentists or general medical practitioners. The total cost for managing this patient cohort was $4,372,455 NZD.

Conclusions: The rate of patient referrals to the Christchurch Hospital OMS service for management of acute odontogenic infections appears to be increasing. There is profound disparity in the use of the current oral health care system, with Māori and Pacific communities over-represented among those referred with acute odontogenic infections.

Introduction

The number of patients presenting to hospital Emergency Departments (EDs) due to preventable odontogenic infections is increasing globally (Burnham *et al*., 2011; Blankson *et al*., 2019; Han *et al*., 2020). Odontogenic infections cause profound pain and have the potential to rapidly spread along tissue planes to involve and compromise critical structures in the head and neck, e.g., the oropharyngeal airway. In such cases, urgent medical and surgical interventions are critical to prevent severe consequences such as sepsis, multi-organ failure, airway obstruction and death (Ogle, 2017). These patients are routinely referred to, and require management by, oral and maxillofacial surgery (OMS) services.

Conversely, some patients with relatively minor odontogenic infection present acutely to ED and are treated and discharged the same day by on-call OMS staff (Hwang *et al*., 2011; Mckenzie *et al*., 2022). This draws valuable public resources away from other high-need patient groups requiring OMS input, such as those with pathology or facial trauma. In a previous study of odontogenic infections at Christchurch Hospital between 1st May 2008 and 30th April 2009, 202 patients presented (Hwang *et al*., 2011). Of those patients, 86% did not require in-patient admission and were treated and discharged the same day. Arguably, private dentists could manage these patients in the community, sparing on-call OMS resources. Presenting to ED for minor odontogenic infections suggests a lack of access to dental care in the community because, as in New Zealand (NZ), patients aged ≥ 18 years must pay privately for services. Cost is a likely barrier, as 38.9% of adults avoided dental care in 2020/21 for this reason, and 52.4% only visited a dental health care worker when they had an acute problem (Ministry of Health, 2021a; Ministry of Health 2021b).

In the same 2008 – 2009 study at Christchurch Hospital, Māori were approximately twice as likely, and Pacific peoples approximately three times as likely as NZ Europeans to present acutely for treatment. This suggests a lack of access to primary care dental services among Māori and Pacific peoples in particular. Such inequality in access may also lead to differences in the severity of infection between ethnicities at the time they present for acute management. However, this has not been studied previously. Lack of access to primary care dental services could result in patients with less severe infection presenting to ED for treatment (i.e., patients who could have been managed in the community had care been accessible). Alternatively, lack of access could result in patients presenting with infection of greater severity as the provision of care is delayed.

Since the study of Hwang *et al*. (2011), no further published papers have examined ethnic disparities in referral rates to public hospital OMS services in NZ. Moreover, there are no NZ data describing the severity of infection experienced by patients, nor the routes by which patients are referred to public OMS service, be that directly via ED, or through primary care providers such as general dentists and general medical practitioners. This information will be of value to policy makers and will help inform future strategies to reduce ethnic disparities in unmet oral health needs in NZ.

Aim

This study aimed to determine the number of patients with acute odontogenic infections referred to the Christchurch Hospital OMS service from 1st January 2018 to 31st December 2020. Additionally, it sought to examine the differences in referral patterns across different ethnic groups, the level of care required, and the financial cost attributable to their management.

Hypotheses

We expected to find that Māori and Pacific peoples were over-represented among patients referred. The questions of different experiences between ethnicities were addressed formally using two pairs of related research hypotheses; H_{1a}^{*}: "Māori referred with odontogenic infections are more likely than NZ Europeans to be referred directly via ED"; H_{1b}^{*}: "Pacific peoples referred with odontogenic infections are more likely than NZ Europeans to be referred directly via ED"; H_{2a}^{*}: "Māori and NZ Europeans referred with odontogenic infections require different levels of care"; H_{2b}^{*}: "Pacific peoples and NZ Europeans referred with odontogenic infections require different levels of care". The level of care required was considered to be a proxy measure of the severity of infection.

Hypotheses H_{1a}^{*} and H_{1b}^{*} are one-sided because of the suggestion in earlier work that Māori and Pacific peoples are over-represented and because of the practical importance of drawing such a conclusion. Hypotheses H_{2a}^{*} and H_{2b}^{*} are two-sided because of ambiguity in the relationship between referral to OMS services for treatment and the severity of infection.

It was not our intention to carry out simultaneous comparisons of Māori and Pacific peoples, which would weaken the statistical strength of our conclusions in the comparisons with NZ Europeans. Separate (post hoc) comparisons between Māori and Pacific peoples are described in the Appendix.

Methods

Locality authorisation and ethical approval were obtained from the Canterbury District Health Board (DHB) research office in conjunction with Te Komiti Whakarite, the Canterbury DHB Māori health research committee.

This was a clinical audit of all patients with odontogenic infections referred acutely to the OMS service at Christchurch Hospital, NZ from 1st January 2018 to 31st December 2020. Patients were identified using a departmental patient database and were cross-referenced with the Canterbury DHB electronic health record system.

Referral rates

Overall referral rates were calculated for each of the three studied years using the size of the Canterbury population from the 2018 Census as the denominator. For ethnicity-specific referral rates, the denominator was the size of the population in the Canterbury region for that ethnicity taken from the 2018 Census.

Confidence intervals (CI) on the underlying unstandardised rates were calculated using the Wilson 'score' method (Wilson, 1927). Our study sample is exhaustive in containing every patient in the Canterbury region in the study period. So, generalising from a sample statistic to an underlying population parameter means generalising either in space to the whole of NZ or in time to a future represented by the study period. We interpret the CIs presented in this paper as pertaining to the true rates and proportions existing in the Canterbury region in the years ahead: we do not immediately assume that our conclusions apply to other regions of NZ.

To determine if there was a statistically significant difference in referral rates between Māori and NZ Europeans, and between Pacific peoples and NZ Europeans, direct age-standardised referral rates were calculated using the 2001 Census Māori population as the standard using five-year age groups as per the Ministry of Health position paper (Ministry of Health, 2018). The ratio of standardised rates (rate ratio) and associated 95% CIs between the two ethnic groups in each comparison were calculated using a modified method of Dobson *et al*. (1991). If the CI of the rate ratio did not include the number 1, the ratio was said to be statistically significant.

To estimate whether the disparity in referral rates between Māori and NZ Europeans, and between Pacific peoples and NZ European has changed since 2008 – 2009, the ratio of referral rates from Hwang *et al*. (2011) and the present study were compared. This involved calculating ethnicity specific referral rates from 'Table 1' in Hwang *et al*. (2011), using the size of the population in the Canterbury region for that ethnicity from the 2006 Census as the denominator. Ethnicity specific referral rates for the present study were calculated for the period 1st May 2018 to 30th April 2019, using 2018 Census data as the denominator. This allowed a comparison of rate ratios over exactly a 10-year period and avoided any influence the 2020 COVID-19 lockdown periods may have had on patient referrals. Rate ratios for Māori to NZ European referrals and Pacific peoples to NZ European referrals were calculated for both studies. The ratio (and associated 95% CIs) of the analogous rate ratios (i.e., present study ÷ Hwang *et al*. (2011)) were then calculated. For this analysis, age-standardisation was not possible as the age structure of the different ethnic populations was not provided in Hwang *et al*. (2011). Hence, this was limited to a comparison of unstandardised rate ratios.

Table 1. Referral rates stratified by ethnicity and age.

Year	n	(%)	Rate per 1,000					
2018	189	(21.0)	0.32	[0.27, 0.36]				
2019	331	(36.7)	0.55	[0.50, 0.61]				
2020	380	(42.2)	0.63	[0.57, 0.70]				
Ethnicity	**n**	**(%)**	**Unstandardised rate per 1,000†**		**Age-standardised rate per 1,000†**			
NZ European	537	(59.7)	1.09	[1.00, 1.18]	1.06	[0.96, 1.17]		
Māori	210	(23.3)	3.74	[3.27, 4.28]	3.83	[3.32, 4.39]		
Pacific peoples	58	(6.4)	3.09	[2.39, 3.99]	3.01	[2.28, 3.89]		
Asian	43	(4.8)	0.65	[0.48, 0.87]	0.67	[0.47, 0.93]		
Middle Eastern/Hispanic/African	8	(0.9)	1.10	[0.56, 2.16]	0.72	[0.29, 1.44]		
Other	44	(4.9)	5.32	[3.96, 7.13]	4.52	[3.11, 6.28]		
Age group	**n**	**(%)**	**Age-specific rate per 1,000‡**		**Rate ratio (Māori to NZ European)**		**Rate ratio (Pacific peoples to NZ European)**	
0 – 9	60	(6.7)	0.83	[0.64, 1.06]	3.32	[1.78, 6.17]	5.82	[2.85, 11.88]
10 – 19	33	(3.7)	0.45	[0.32, 0.63]	3.22	[1.46, 7.04]	-	-
20 – 29	250	(27.8)	2.95	[2.60, 3.33]	3.62	[2.73, 4.80]	2.35	[1.42, 3.90]
30 – 39	212	(23.6)	2.72	[2.38, 3.11]	4.77	[3.53, 6.45]	2.03	[1.09, 3.76]
40 – 49	144	(16.0)	1.80	[1.53, 2.12]	2.78	[1.77, 4.37]	4.74	[2.59, 8.67]
50 – 59	111	(12.3)	1.38	[1.15, 1.66]	2.20	[1.25, 3.87]	1.76	[0.52, 5.56]
60 – 69	55	(6.1)	0.85	[0.66, 1.11]	0.88	[0.21, 3.63]	5.11	[1.58, 16.43]
70 – 79	22	(2.4)	0.53	[0.35, 0.80]	2.03	[0.27, 15.28]	7.89	[1.05, 59.49]
80+	13	(1.4)	0.54	[0.32, 0.93]	-	-	-	-

% refers to the percentage of patients in the entire study sample. Values in square brackets represent lower and upper 95% confidence limits. † and ‡: rates are for the entire three-year study period and were calculated using the size of the population in the Canterbury region for that ethnicity (†) or age-group (‡) taken from the 2018 Census as the denominator. Rate ratios could not be calculated when there were zero patients within a sub-group being compared.

Referral pattern

Our research hypotheses H_{1a}^* and H_{1b}^* represent one-sided 'alternative' hypotheses examinable by testing the corresponding complementary null hypotheses H_{1a}: "The probability that a referral comes from ED is no greater for Māori than for NZ Europeans" and H_{1b}: "The probability that a referral comes from ED is no greater for Pacific peoples than for NZ Europeans". In relation to H_{1a}, the difference being studied is the probability for Māori minus the probability for NZ European, Ω_{ME}. A larger estimate would correspond to greater evidence against the null hypothesis, i.e., greater evidence for the research hypothesis H_{1a}^*. Analogous comments apply with H_{1b} and the probability for Pacific peoples minus the probability for NZ European, Ω_{PE}.

Hypotheses H_{1a} and H_{1b} were tested simultaneously in one-tailed procedures with family-wise type I error-rate $\alpha = 0.05$. The unadjusted p-values for the tests were found using a computationally-intensive resampling method based on exact binomial probabilities, meaning there was no need for a standard large-sample approximation. Then the p-values were adjusted for simultaneity by doubling according to the Bonferroni principle. The method involved the calculation and inversion of individual 97.5% lower confidence limits on the two differences in proportions. Together, these define a semi-infinite 95% confidence region, and inversion gives the appropriate hypothesis tests.

Level of care required

Similarly, for two-sided hypotheses H_{2a}^* and H_{2b}^*, the null hypotheses were H_{2a}: "The levels of care required by Māori and NZ Europeans are the same" and H_{2b}: "The levels of care required by Pacific peoples and NZ Europeans are the same". These null hypotheses were tested using Somers' *D*, which enables the comparison of variables (in this case, two ethnicities) in the presence of ordered categorical data (in this case, three levels of care: Treated by OMS and discharged from ED the same day < Admitted to the OMS ward < Admitted to the intensive care unit (ICU)). The underlying parameter estimated by Somers' *D* is Δ. A family-wise type I error-rate of $\alpha = 0.05$ was obtained by calculating individual 97.5% CIs on the value for Māori compared to NZ European, Δ_{ME}, and the value for Pacific peoples compared to NZ European, Δ_{PE}. Together, these define a 95% confidence region, and inversion gives the appropriate hypothesis tests. The unadjusted p-values were doubled to allow for the simultaneity.

Statistical analysis was caried out using R version 4.1.0. Statistical significance was accepted when $p < 0.05$, whether the analysis was one-tailed or two-tailed.

Descriptive analysis and cost analysis

In addition, we also collected descriptive data on the aetiology of infection (dental caries, infected extraction socket etc), detail of any pre-referral antibiotic therapy, eventual management by the OMS service, and the types of anatomical spaces explored surgically among patients requiring surgical treatment under general anaesthesia (GA). In cases where records did not provide a specific aetiology of infection, the documented history, clinical findings, and radiographs were interpreted by both the first and second authors and a specific diagnosis/aetiology was agreed upon.

Finally, we obtained the financial cost attributable to managing this patient sample. Patient-specific hospital fees for ED assessments, radiographic investigations, ward admissions, theatre time, and review appointments were obtained from the Christchurch Hospital Department of Finance. Individual costs were calculated based on the number of these required by each patient specifically.

Results

Table 1 shows summary statistics associated with the rates of patient referrals by age and ethnicity. During the three-year study period (1st January 2018 to 31st December 2020) exactly 900 patients with odontogenic infections were referred acutely to the OMS service at Christchurch Hospital. The mean, median, minimum and maximum ages of the patients were 36.7, 34, 2 and 95 years respectively. The majority of patients (91.6%) were aged ≥18 years. Just over half of all patients were male (54.0%). Table 2 shows that fewer patients were referred during the COVID-19 lockdown period of 2020, when there were restrictions on the provision of dental care in the primary care setting, than during the corresponding period in 2019, when there was no lockdown.

Referral rates

The rate of patient referrals per 1,000 of the general Canterbury region population doubled from 0.32 in 2018 to 0.63 in 2020 (rate ratio = 2.01, 95% CI [1.69, 2.40]) (Table 1). In 2020, the number of patients referred surpassed an average of one per day. NZ Europeans made up the majority of the study sample but, for all age groups <50 years, both Māori and Pacific peoples were referred at significantly higher rates than NZ Europeans. Even after standardisation, both Māori and Pacific peoples were referred at significantly higher rates than NZ Europeans with the age-standardised rate ratio of referrals for Māori to NZ Europeans being 3.60, 95% CI [3.04, 4.26], and for Pacific peoples to NZ Europeans being 2.83, 95% CI [2.11, 3.73].

The age distribution of those referred was biased towards younger adults, with the highest age-specific referral rate over the three-year study period being observed in the 20 – 29 years age group (2.95 per 1,000 of the general Canterbury region population aged 20 – 29 years). The 95% confidence-interval estimate of the underlying referral rate for the future for those aged 20 – 29 years is 2.60 – 3.33 per 1,000. A similar referral rate was observed in the 30 – 39 years age group (2.72, 95% CI [2.38, 3.11]).

Table 2. Number and rate (per 100,000 per week) of patients referred during the 2020 COVID-19 lockdown periods compared to the corresponding periods in 2019.

	Alert Level 4		Alert Level 3		Alert Level 2	
Year	*n*	(rate)	*n*	(rate)	*n*	(rate)
2019	27	(0.93)	19	(1.39)	29	(1.30)
2020	21	(0.72)	13	(0.95)	24	(1.08)

Note: COVID-19 Alert Level 4 was the highest lockdown level in NZ's 4-tier system.
Alert Level 4 spanned the dates: 25th March 2020 – 27th April 2020.
Alert Level 3: 28th April 2020 – 13th May 2020.
Alert Level 2: 14th May 2020 – 8th June 2020.
Rates were calculated using the size of the Canterbury population from the 2018 Census as the denominator.

Table 3. Summary statistics for the tests of hypotheses H_{1a} and H_{1b}; pattern of referral, and H_{2a} and H_{2b}; level of care required.

	NZ European		Māori		Pacific peoples	
Referrer	*n*	(%)	*n*	(%)	*n*	(%)
ED	406	(75.6)	176	(83.8)	49	(84.5)
Other sources (not ED)	131	(24.4)	34	(16.2)	9	(15.5)
Total	537	(100)	210	(100)	58	(100)
Level of care	*n*	(%)	*n*	(%)	*n*	(%)
Discharged from ED	385	(71.7)	162	(77.1)	45	(77.6)
Admitted to ward	127	(23.6)	38	(18.1)	8	(13.8)
Admitted to ICU	25	(4.7)	10	(4.8)	5	(8.6)
Total	537	(100)	210	(100)	58	(100)

For the comparison of Māori to NZ European referrals over a 10-year period, the ratio of unstandardised rate ratios (i.e., present study ÷ Hwang *et al*. (2011)) was calculated to be 2.15, 95% CI [1.28, 3.61]. For the comparison of Pacific peoples to NZ European referrals, this was calculated to be 1.22, 95% CI [0.56, 2.65].

Referral pattern

Just over three quarters (77%) of patients presented directly to ED and were subsequently referred to the OMS service. One in ten were referred acutely by their general medical practitioner, and 5.7% by general dentists in primary care, 2.9% by the other medical teams at Christchurch Hospital, 2.2% by the Christchurch Hospital Dental Department relief-of-pain clinic, 1.6% by private OMS, and 0.1% by other dental specialists in private practice.

Table 3 shows the number and percentage of NZ European, Māori, and Pacific peoples referred by ED and by other sources ('Not ED'). Regarding hypotheses H_{1a}^{*} ("Māori referred with odontogenic infections are more likely than NZ Europeans to be referred directly via ED") and H_{1b}^{*} ("Pacific peoples referred with odontogenic infections are more likely than NZ Europeans to be referred directly via ED"), individual 97.5% lower confidence limits on the differences in proportions Ω_{ME} and Ω_{PE} are calculated to be 0.013 and −0.034 respectively. So, taking the two comparisons as a family, we have sufficient evidence at the 95% confidence level to conclude that the underlying proportion of Māori being referred from ED is greater than the underlying proportion of NZ Europeans being referred from ED ($p_{adjusted} = 0.02$), but the same cannot be said for Pacific people ($p_{adjusted} = 0.09$). The point estimates of Ω_{ME} and Ω_{PE} are 0.08 and 0.09. If calculated individually, 95% confidence intervals for Ω_{ME} and Ω_{PE} are [0.01, 0.15] and [−0.03, 0.20] respectively.

Level of care required

Almost three quarters of patients (72.6%) were treated in ED (by the OMS service) and discharged the same day. Almost one quarter (22.4%) required in-patient level care with admission to the OMS ward. An additional 5% required admission to the ICU. Two patients who were admitted to the ICU required a tracheostomy.

Table 3 also shows the number and percentage of NZ European, Māori, and Pacific peoples requiring various levels of care (treated and discharged from ED, admitted to the OMS ward, admitted to the ICU). Regarding hypotheses H_{2a}^{*} ("Māori and NZ Europeans referred with odontogenic infections require different levels of care"), and H_{2b}^{*} ("Pacific peoples and NZ Europeans referred with odontogenic infections require different levels of care"), individual 97.5% CIs for Δ_{ME} and Δ_{PE} are calculated to be [−0.14, 0.04] and [−0.20, 0.13], and together these intervals simultaneously form a 95% confidence region for Δ_{ME} and Δ_{PE}. So, based on these data, we do not have sufficient evidence at the 95% confidence level to conclude that either H_{2a}^{*} or H_{2b}^{*} is true.

Aetiology of infection

The most common sources of infection for patients were carious teeth and retained roots (75.3%, n = 678), followed by infected extraction sockets (11.2%, n = 100), periodontally involved teeth (4.4%, n = 40), pericoronitis (4.1%, n = 37), failed root canal treated teeth (2.8%, n = 25), cracked teeth (2%, n = 18), gingival abscess (0.1%, n = 1), and peri-implant abscess (0.1%, n = 1).

Pre-referral antibiotic therapy

Just over one quarter of all patients (28.2%, n = 254) had prior management with oral antibiotics in the primary care setting before being referred to the OMS service. The vast majority of these patients were prescribed oral antibiotics by either general dentists (n = 171 patients) or general medical practitioners (n = 76 patients).

Management by OMS

Almost all patients (88.9%) required an operative procedure (tooth extraction/incision and drainage of an abscess) (n = 809 procedures in 800 patients). One in ten patients (11.1%) had limited cellulitis and were managed non-operatively with either intravenous or oral antibiotics.

OMS house surgeons (recent graduate dentists in their first or second year of practice) were the primary operators for almost three quarters (69.0%) of operative procedures. OMS registrars managed one quarter (24.8%), and OMS consultants the rest. A total of 1074 teeth were extracted. Just over three quarters of patients (77.4%) who required an operative procedure were treated under local anaesthetic. 181 patients required a total of 190 surgical procedures under GA. Patients were admitted to the OMS ward for a total of 593 patient days and to the ICU for 145 patient days.

Of the 254 patients who received prior management with oral antibiotic in the primary care setting, nearly half (49.2%) underwent a simple dental extraction or intra-oral drainage of an abscess by OMS house surgeons and were discharged the same day from ED. House surgeons also treated and discharged from ED over half (62.6%) of all patients referred by general dentists working in private practice in the community, and two thirds (67.4%) of patients referred by general medical practitioners.

Anatomical spaces explored surgically

Among patients requiring treatment under GA (190 procedures in 181 patients) there were a total of 272 anatomical spaces explored (Figure 1). Of these, the submandibular space was the most common (40.2%, n = 109), followed by buccal (19.9%, n = 54) and sublingual (10.3%, n = 28) spaces. Rarely explored (but high-risk) spaces included retropharyngeal (0.4%, n = 1), and orbital (0.4%, n = 1).

Cost analysis

The total cost for managing this patient sample was $4,372,455 NZD. These fees are not charged to patients. The mean cost of care per patient was $4,858. The median cost was $726. For the 653 patients who were treated and discharged from ED on the same day, the total cost of care was $562,800 (mean = $862). For the 202 patients who required overnight admission to the ward, the total cost was $1,922,616 (mean = $9,518), and for the 45 patients who required ICU admission, in addition to nights spent on the ward, the total cost was $1,887,039 (mean = $41,934).

The combined cost for radiographic investigations for the study sample was $430,111. The set of investigations consisted of 861 orthopantomograms and periapical radiographs, 228 computed tomography scans, and 115 other radiographs such as chest X-rays to assess nasogastric tube placement for patients who remained intubated post-operatively in the ICU.

The combined cost for ED assessment and overnight ward stays, including ICU, was $2,300,053. This figure includes general costs for administering antibiotics, analgesics, the patients' regular medications, and blood tests.

There were 190 operating sessions under GA, being 10,329 minutes (172.15 hours) of operating time. These represent a cost of $1,483,846. Of note, 77 patients required an awake fibre-optic nasotracheal intubation.

In total, there were 617 out-patient follow-up appointments representing a cost of $158,445.

Discussion

This paper describes a clinical audit undertaken to determine the number of patients referred to the Christchurch Hospital OMS service for management of acute odontogenic infections over a three-year period. To the best of the authors' knowledge, this is the first study in NZ to examine specific ethnic differences in referral rates to a public hospital OMS service. This is also the first NZ study to describe the routes by which patients with acute odontogenic infections are referred to a public hospital OMS service, and to quantify the cost of managing those referred. This study therefore provides useful information to policy makers and will help inform future strategies to reduce ethnic disparities in unmet oral health needs in NZ. However, this was a single-centre study so the results may not necessarily be generalisable to populations in other regions of NZ. Also, due to this study's retrospective nature, our aims were constrained by what data we knew to be routinely collected. Areas where additional data may have provided valuable insights are discussed below. The quality of the data also relied on the accuracy of patient records. While uncommon, some records lacked details, such as not providing a specific aetiology of the odontogenic infection (dental caries, infected extraction socket etc). By relying on the documented history, clinical findings, and radiographs to retrospectively assign a specific diagnosis/aetiology, some incorrect diagnoses may have been made.

The rate of patient referrals noticeably increased year on year. We expected the rate of patient referrals to increase during the 2020 COVID-19 lockdown period when there were restrictions on the provision of dental care in primary practice. However, we found a reduction in referral rates during the 2020 lockdown period compared to the corresponding period in 2019 when there were no lockdowns. While unexpected, similar

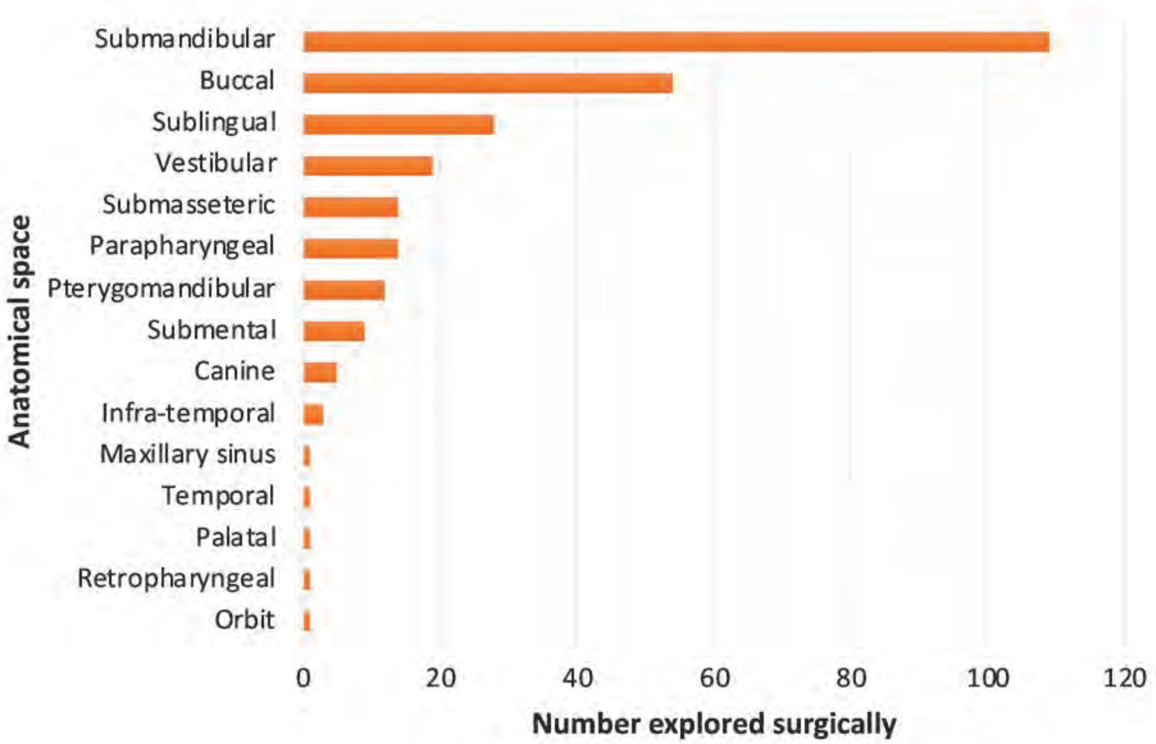

Figure 1. Number and type of anatomical spaces explored surgically in patients who required surgical treatment under general anaesthetic (n = 190 procedures in 181 patients).

findings have been reported elsewhere (Dang *et al*., 2021). This demonstrates that the year-on-year increase in the rate of patient referrals was not due to patient overflow from reduced capacity in primary care during the COVID-19 lockdowns.

The question of initial interest related to the possibility of over-representation of Māori and Pacific peoples among those referred. While NZ Europeans made up the majority of the patients, a comparison of age-standardised referral rates showed that Māori and Pacific peoples were referred at approximately 3.60 and 2.83 times the rate of NZ Europeans respectively. These findings are similar to other studies which also showed an over-representation of Māori and Pacific peoples in hospital admissions for dental treatment (Whyman *et al*., 2014; Mckenzie *et al*., 2021). This issue is therefore widespread in NZ.

Compared to the results of a similar study at Christchurch Hospital in 2008 – 2009 (Hwang *et al*., 2011), the difference in referral rates between Māori and NZ Europeans has increased considerably. This suggests that, since 2008 – 2009, disparities in oral health needs between Māori and NZ Europeans in the Canterbury region have widened. While Pacific peoples continued to be referred at significantly higher rates than NZ Europeans, the difference in referral rates between the two ethnicities remains similar to 2008 – 2009. A meaningful comparison of rates of disease between two ethnicities ought to take into account differences in age structure in the two populations. However, a comparison of age-standardised rates was not possible here as age structures were not provided in Hwang *et al*. (2011).

We acknowledge that Hwang *et al*. (2011) included patients referred to Christchurch Hospital with odontogenic pain or infection, whereas the present study only included patients referred specifically to the OMS service. At Christchurch Hospital, any patient referred acutely to the OMS service is triaged through ED, however, not every patient presenting to ED with an odontogenic infection requires a subsequent referral to the OMS service. A similar triage/referral process exists at Waikato Hospital, and a recent clinical audit of dental presentations to ED over the five-year period 2015 – 2019 found that just over one third of patients (36.4%) with odontogenic infection were subsequently referred to the Waikato OMS service (Mckenzie *et al*., 2022). A similar proportion of patients are likely referred to the Christchurch Hospital OMS service, however we cannot be certain of this. Had the present study investigated all patients with odontogenic infections presenting to Christchurch Hospital ED (i.e., not specifically referred to the OMS service), a more appropriate comparison of referral rates to Hwang *et al*. (2011) could have been made. We may well have observed greater disparities in referral rates between ethnicities over time than those stated above.

Māori (but not necessarily Pacific peoples) were more likely than NZ Europeans to initially present themselves to ED than be referred from other sources such as general dentists or general medical practitioners. This suggests poorer access for Māori to primary care services. Such inequality in access might be expected to lead to a difference in the severity of infection observed at referral. However, there was no statistically significant difference in the levels of care required between Māori and NZ Europeans (or between Pacific peoples and NZ Europeans). Our results suggesting inequality in access to primary care services for Māori are supported by data from the 2020/21 NZ Health Survey, which showed that just over one third of Māori respondents had visited a dental health care worker in the last 12 months, compared to almost half for all ethnicities combined (Ministry of Health, 2021a). Additionally, just over two thirds of Māori reported only visiting a dental health care worker when they were aware of problems, compared to just over half for all ethnicities combined. The same survey also showed that just over half of all Māori identified themselves as having unmet needs for dental health care due to cost, compared to just over one third for all ethnicities combined. This disparate access to care is not exclusive to dentistry, as the proportion of Māori who reported unmet needs for general medical care due to cost and lack of transport was also higher than all ethnicities combined. The retrospective nature of the present study meant we could not explore the reasons why patients who presented to ED did not (or could not) access primary health care services prior. However, we expect the barriers to be the same as those identified in the 2020/21 NZ Health Survey, i.e., cost and lack of transport, with the probable addition of dental anxiety. Exploring the impact of these barriers and identifying others would be important in a subsequent prospective study.

In NZ, preventive dental care is free (publicly-funded) under child and adolescent oral health services from birth until 18 years of age. Ministry of Health data shows that there was incomplete uptake of this service among children aged 1 – 14 years in 2020/21 (~71.0%) (Ministry of Health, 2021a). However, there was no statistically significant difference in the likelihood of having visited a dental professional within the last 12 months between Māori and non-Māori children, and between Pacific and non-Pacific children. Given these results, it could be expected that there would be no significant difference in the likelihood of requiring referral to hospital OMS services for management of acute odontogenic infection between Māori, Pacific, and NZ European children. However, this was a national study so these results may not apply to the Canterbury region specifically. Indeed, our results show that both Māori and Pacific children were referred at significantly higher rates than NZ Europeans. Considering referral rates to the OMS service as a proxy measure for unmet oral health needs, our results demonstrate that ethnic disparities exist from childhood in the Canterbury region.

At age 18, patients are no longer eligible for publicly-funded child and adolescent oral health services and must pay privately for dental services. With cost prohibiting just over one third of adults from accessing private dental services in 2020/21 (Ministry of Health, 2021b), it is not surprising that the highest age-specific referral rate observed in the present study was among young adults aged 20 – 29 – shortly after they exit the publicly-funded service. In general, people in this age group are either engaged in further study/training or have recently entered the workforce and are on relatively low wages compared to older age groups. Hence, policy makers could consider targeting the 20 – 29-year age group to have the greatest overall impact on referral rates to hospital OMS services, whilst also combating ethnic disparities.

Unlike other regions in NZ, the Canterbury region (with the exceptions of Methven and the Burnham Military Camp) does not currently have community water fluoridation (Environmental Health Intelligence, 2021). This may have contributed, at least in part, to the high proportion of patients who were referred with acute odontogenic infection arising from dental caries (75.3%). Community water fluoridation likely reduces oral health inequity between populations of different socioeconomic deprivation levels (Gluckman *et al*., 2014; Sapere Research Group, 2015). The present study did not specifically examine referral rates across deprivation levels, however, Māori and Pacific populations in general experience greater deprivation than NZ Europeans. Therefore, policy makers should consider community water fluoridation as a low-agency method of reducing both overall referral rates and ethnic disparities in referral rates to hospital OMS services for management of acute odontogenic infection due to dental caries.

One tenth of patients (n = 95) were referred by general medical practitioners whereas only 5.7% (n = 51) were referred by general dentists. It seems unusual that patients afflicted by odontogenic infection would elect to seek care with their general medical practitioner over a general dentist. However, given the much greater cost to the patient in seeking care with a general dentist in private practice, it is understandable why some see their general medical practitioner instead. Another explanation is that the general dentists were, obviously, better equipped to manage acute odontogenic infections than general medical practitioners, hence they did not feel the need to refer patients to a tertiary hospital OMS service. Two thirds of patients referred by general medical practitioners were seen, treated via a simple dental extraction or intra-oral incision and drainage of an abscess, and discharged from ED on the same day by OMS house surgeons. Therefore, it is likely that these patients could have been adequately treated by general dentists in the community had private dental services been more accessible, sparing valuable hospital resources.

Just over one quarter of patients had prior management in the primary care setting with oral antibiotics only, most of which were prescribed by general dentists or general medical practitioners. Almost half of these patients were treated and discharged from ED the same day by OMS house surgeons. This finding suggests a failure of source control in many patients who initially sought care in the community. Given that these patients were also appropriately managed by OMS house surgeons, it is likely that general dentists could have provided adequate care in the community, likewise sparing hospital resources. The authors wish to emphasise that first-line treatment of an odontogenic infection is prompt removal of the infective source via either dental extraction, pulpectomy, or subgingival debridement (depending on the aetiology), and drainage of any associated purulent collections. Antibiotics are used only as an adjunctive treatment to the above when there are systemic signs of infection, for example fever (>38° C).

At the other end of the severity spectrum, one fifth of patients (n = 181) required surgical treatment under GA. Almost two thirds of these patients (n = 109) required surgical exploration of the submandibular space. Spreading odontogenic infections that involve deep neck spaces such as this have the potential to compromise the airway leading to rapid deterioration of the patient's condition. Moreover, almost half of the patients (42.5%, n = 77) treated under GA required awake fibre-optic nasotracheal intubation, and one quarter (24.9%, n = 45) required post-operative admission to the ICU for airway protection. Awake fibre-optic nasotracheal intubation is a resource-intensive method of intubation reserved for patients who, following specialist anaesthetic review, are deemed to have a difficult or high-risk airway due to trismus, stridor, pain on swallowing, inability to manage their own secretions, and/or airway deviation. The high proportion of patients requiring either awake fibre-optic nasotracheal intubation and/or post-operative ICU admission reflects the high degree of airway involvement in spreading odontogenic infections in the study sample. GA procedures and post-operative intubation in the ICU also predispose patients to additional complications such as ventilator-associated pneumonia, venous thromboembolism, and delirium which contribute to overall patient morbidity. It is unknown what proportion of patients in the present study suffered these complications. This represents an unfortunate omission from our data collection that may have provided further insights into the consequences of severe odontogenic infection experienced by this patient sample.

The total cost for managing this patient sample was $4,372,455. This total does not include the cost of dental rehabilitation carried out in the private sector, nor does it consider the personal cost to patients for time off work and missed social opportunities and obligations whilst they were an in-patient or recovering from the infection. The mean cost of care per patient was $4,858. The median cost was $726. We have chosen to report the median alongside the mean because a small proportion of patients required care that was much more costly, i.e., post-operative ICU admission and, to a lesser extent, treatment under GA. In any case, these costs are in significant contrast to that of a simple extraction of a single tooth in private dental practice, which averages $233 in the Canterbury region (NZDA Fee Survey, 2020).

Conclusion

The rate of patient referrals to the Christchurch Hospital OMS service for management of acute odontogenic infections appears to be rising annually. Managing these patients is costly, more so than earlier intervention, and draws valuable public resources away from other high-need patient groups. There is substantial inequity within the current oral health care system, with Māori and Pacific peoples over-represented among those referred acutely. This research highlights the need for greater accessibility to oral health care services in primary care/community settings in NZ.

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Graham DO and Erasmus J conceptualised the study, Graham DO and Schuurman NG collected the data, Graham DO analysed the data and wrote the manuscript, Willink R designed and conducted the statistical analysis and contributed to writing of the manuscript. The authors declare no conflicts of interest. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Appendix

As requested by a reviewer, we include here results of comparisons between Māori and Pacific ethnic groups. These were not among our pre-stated aims, though we appreciate that these comparisons may be of interest to researchers at a future point in time. These post hoc supplementary comparisons necessitated the formulation of hypotheses to test – though these are not necessarily the hypotheses of the authors. Each individual supplementary comparison was carried out with a with a type I error-rate of $\alpha = 0.05$, and no technique (e.g., Bonferroni) has been applied to correct for the simultaneity of inference. As with the hypotheses in the text, the relevant summary statistics are found in Table 3.

The hypotheses are denoted with the subscript ‘x’ to distinguish them from the two pairs (families) of hypotheses (H_{1a}^*/H_{1b}^* and H_{2a}^*/H_{2b}^*) in the main text and to indicate their purely exploratory nature. The first supplementary hypothesis is H_{1x}^*: “The proportion of Māori referred with odontogenic infections directly via ED (among all Māori referred) is different from that of Pacific peoples”. Unlike H_{1a}^* and H_{1b}^* in the main text, hypothesis H_{1x}^* is two-sided because of the lack of previous evidence to suggest an effect in either direction. The second supplementary hypothesis is H_{2x}^*: “Māori and Pacific peoples referred with odontogenic infections require different levels of care”. As with H_{2a}^* and H_{2b}^*, this is two-sided because the relationship between referral to OMS services for treatment and the severity of infection is unclear.

The analysis of referral rates follows the same procedure as described in the main text. For Māori compared to Pacific peoples, the age-standardised rate ratio of referrals was 1.27, 95% CI [0.95, 1.73]. For the comparison of referrals for Māori to Pacific peoples over a 10-year period, the ratio of unstandardised rate ratios (i.e., present study ÷ Hwang *et al.* (2011)) was calculated to be 1.77, 95% CI [0.74, 4.23]. Neither result is conclusive if used as a test.

Hypothesis H_{1x}^* is examined by testing the complementary null hypothesis, H_{1x}: “the probability that a referral comes from ED is the same for Māori as for Pacific peoples”. The probability for Māori minus the probability for Pacific peoples is denoted Ω_{MP}. We find the point estimate of Ω_{MP} to be −0.01 and that a 95% confidence interval for Ω_{MP} would be [−0.13, 0.10], which would indicate insufficient evidence at the $\alpha = 0.05$ level to reject H_{1x}.

Similarly, the null hypothesis with H_{2x}^* is H_{2x}: “The levels of care required by Māori and Pacific peoples are the same”. This was tested using Somers’ *D*. We would find a 95% confidence interval for Δ_{MP} to be [−0.15, 0.13], which would indicate insufficient evidence at the $\alpha = 0.05$ level to reject H_{2x}.