Report

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New Zealand general dentists' usage and views on caries detection methods

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ABSTRACT

Background and objectives: As understanding of the carious process has increased, so too have technological advances in its diagnosis, with an increased focus on detecting incipient caries to allow non-operative interventions. The aim of this study was to investigate New Zealand (NZ) general dental practitioners' (GDP) preferred methods for caries detection and their views on the available caries detection methods and devices.

Methods: Following ethical approval an online survey and participant information sheet was emailed to all New Zealand registered GDPs with a valid email address. Statistical analysis was carried out using SPSS version 22.0 with the alpha value set at 0.05.

Results: The participation rate was 28.6% (294/1027). Of the nine modern caries detection devices available, transillumination, DIAGNODent and FOTI were the most commonly known. Although transillumination devices were owned by 72.9% of participants, only 40.2% used them regularly. DIAGNODent devices were owned by 42.2% but only 17.0% regularly used them. Views on individual devices were mixed. The majority still use conventional visual-tactile (86.6%) and digital radiography (77.6%) methods, with many believing that these are effective (77.9%) and efficient (64.3%).

Conclusion: Results showed that conventional caries detection methods currently remain the most common techniques used by GDPs in NZ.

INTRODUCTION

The detection of caries lesions forms an integral part of every dentist's practice and is the initial step of a systematised diagnostic procedure, followed by evaluation of severity and level of activity (Guerrieri et al., 2012). Early detection of lesions can allow for non-operative interventions thus preserving tooth structure and improving the long-term prognosis of the tooth. Although traditional diagnostic methods – visual-tactile examination and bitewing radiographs – have formed the backbone of caries detection, advances in the understanding of the carious process has prompted the need to both measure and classify the extent of lesion demineralisation (Pretty, 2006). As a result, a large variety of caries detection devices are now available. These can be broadly divided into enhanced visual, instrumental and imaging methods (Pretty and Ellwood, 2013) and can assist not only in caries detection, but may contribute during diagnostic and treatment decision-making (Amaechi, 2009).

Visual examination of the tooth surface, preferably after cleaning, can reveal changes in its colour, translucency and integrity. The surface appearance may differ after drying, as the first visual changes in enamel may not be visible on a wet surface. Use of a blunt or rounded probe can reveal roughness of the enamel and the presence of any soft or hard deposits. Magnification loupes show improved accuracy of caries diagnosis (Forgie et al., 2002), while studies comparing the use of an operating microscope at 16x magnification have shown no statistically significant difference in accurate diagnosis compared to an unaided visual examination (Erten et al., 2006; Akarslan and Erten, 2009). Intraoral cameras have been shown to significantly increase the probability of making an accurate diagnosis (Forgie et al., 2003; Erten et al., 2006). In all of the afore-mentioned studies, an initial unaided visual examination was carried out followed by the method being investigated, after which the teeth were sectioned and a histological validation performed to determine the actual status of the teeth.

Bitewing radiographs have long been the conventional method for detecting approximal caries. They are easy to take and reproducible for the follow-up of early lesions that are being preventively managed. Higher speed conventional films have lowered the radiation exposure for patients. Digital radiography enables storage of images electronically, the sending of copies to third parties and the magnification and enhancement of images (Feuerstein, 2004). Patients can easily be shown their radiographs for explanation and educational purposes.

Although generally thought of as more recent innovations, technology-based caries detection has been used for several decades (Zero et al., 2014) with research on ultrasound (Lees et al., 1970) and fibre-optic transillumination (FOTI) (Friedman and Marcus, 1970) first published over 40 years ago. Both FOTI and digital imaging fibre-optic transillumination (DIFOTI) make use of the differing indices of light transmission of carious enamel versus sound enamel, with more light absorbed when demineralisation has disturbed the crystalline structure of enamel and dentine (Amaechi, 2009). They are simple, non-invasive and painless, and can be repeated with no risk to the patient (Davies et al., 2001). DIFOTI allows for digital storage of the images and has recently changed from using white light to near-infrared light, as its longer wavelength is able to penetrate the tooth further due to reduced scatter (Sochtig et al., 2014). Optical Coherence Tomography (OCT) is based on the interference of light caused by scattering due to changes in the tissue structure of the tooth (Hall and Girkin, 2004).

Fluorescence can also be used to detect caries. In quantitative light-induced fluorescence (QLF), the increased porosity caused by demineralisation leads to an increase in scattering of the penetrating light with less excitation light reaching the enamel-dentine junction and a darker appearance around the affected area. The DIAGNODent device measures the fluorescence of bacterial products within carious lesions, measuring bacterial

activity but not the degree of demineralisation (Pretty and Maupome, 2004; Pretty, 2006).

Other methods of imaging include the electronic caries monitor (ECM) and electrical impedance spectroscopy (EIS). Both devices use the concept of increased porosity in demineralised areas resulting in a higher fluid content and decreased electrical resistance (Pretty, 2006; Amaechi, 2009). As EIS uses varying electrical frequencies, in contrast to the single fixed-frequency current of ECM, it can obtain a more detailed analysis of the lesion extent (Pretty, 2006).

Dentists are faced with an increasing number of choices when acquiring new diagnostic equipment. Although many are comfortable with visual and tactile examination and radiographs, and may use magnification loupes, there is the temptation to invest in a device that could offer enhanced diagnostic accuracy while still being easy to use, efficient and affordable. While many papers have discussed the technologies available for caries detection and diagnosis, an Internet search, using both PubMed and Google Scholar with the keywords "dental caries", showed only two papers exploring the methods used by general dentists to diagnose caries (Rindal et al., 2010; Gordon et al., 2011). Both arose from the same Dental Practice-Based Research Network (DPBRN) comprising dentists from Alabama/Mississippi, Florida/Georgia, Minnesota, Oregon, Denmark, Norway and Sweden. No research of this kind has been carried out among general dentists on a national basis. The aim of this study was to investigate New Zealand (NZ) general dental practitioners' (GDP) preferred methods for caries detection and their views on caries detection methods and devices. Results of the study may be useful in provoking discussion among GDPs, advising them on what diagnostic tools are currently available, and promoting the uptake of newer technologies.

METHODS

Ethical approval for this study was obtained from the University of Otago Human Ethics Committee (D15/005) and Māori consultation was sought from Ngāi Tahu Consultation Committee according to the University's Policy for Research Consultation with Māori. The study population included all GDPs registered with the Dental Council and with a valid email address. The 1027 eligible participants were contacted via email in March 2015 and provided with a link to the questionnaire using Google Forms. A participant information sheet, which gave a brief explanation of the study, was attached and participants were informed that returning the completed questionnaire would imply consent. After one month, a second wave was sent out to those who had not as yet responded. All participation was voluntary and anonymous. To increase participation, respondents were invited to enter a prize draw.

Questionnaire

A self-administered, 21-question survey was constructed and pretested on a group of dental postgraduate students. This led to improvements in wording and clarity. It consisted of multiple-choice, open-ended, and 5-point Likert-style questions. The first section collected demographic data including age, sex, year and country of graduation, and the main type of current employment. The second section focused on the following information:

i) The participant's personal opinions, experiences and awareness of caries detection methods
ii) Their frequency of use of these caries detection methods
iii) Their reasons for, and against, these caries detection methods.

Table 1. Comparison of demographic characteristics of respondents and concurrently registered GDPs in New Zealand (brackets contain row percentages unless otherwise indicated).

	Respondents	All registered GDPs	P value*
Total number	294	1954	
Gender			0.201
Male	193 (65.6)	1207 (61.8)	
Female	101 (34.4)	747 (38.2)	
Age group (in years)			<0.001
21-39	65 (22.1)	657 (33.6)	
40-49	82 (27.9)	433 (22.2)	
50+	147 (50.0)	864 (44.2)	
Year of graduation			<0.001
1940-1979	56 (19.1)	393 (20.1)	
1980-1999	170 (57.8)	896 (45.2)	
2000-2014	68 (23.1)	665 (34.0)	
Country of primary dental degree			0.133
New Zealand	221 (75.2)	1386 (70.9)	
Other	73 (24.8)	568 (29.1)	
Employment type			<0.001
Private practice	252 (86.9)	1835 (93.9)	
Non private practice	38 (13.1)	119 (6.1)	

**P-value indicates the statistical significance between respondents and all registered GDPs.*

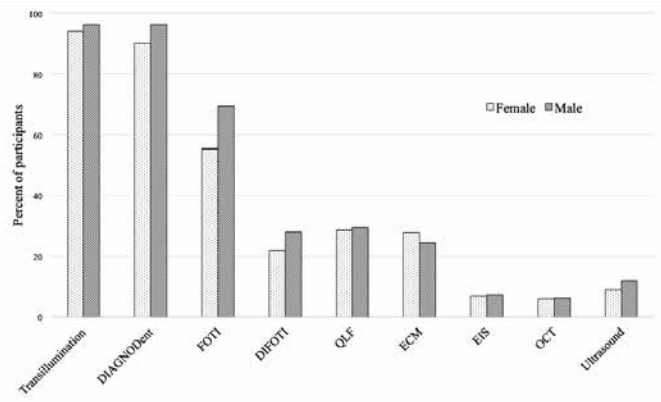

Figure 1. Respondents' awareness of modern detection devices according to gender.

Statistical analysis

Responses were automatically collected via Google Forms and transferred into an IBM Statistical Package for the Social Sciences database (SPSS Version 22.0, Chicago, IL, USA). They were double-checked and cleaned to ensure accuracy, and analysed using SPSS. The chi-square test was used to test for the significance of the observed associations, with an alpha level of 0.05.

RESULTS

Participation

Of the 1027 eligible participants, 294 GDPs responded, giving an overall response rate of 28.6%. The majority worked in private practice (252, 86.9%), with more than half being male (193, 65.7%), having graduated between 1980-1999 (170, 57.8%) and/or New Zealand graduates (221, 75.2%). Half of the respondents were aged over 50 years (147, 50%). The socio-demographic characteristics of both the respondents and all registered New Zealand GDPs are shown in Table 1. Statistically significant differences between the two groups were found with regards to age (P<0.001), year of graduation (P<0.001) and employment type (P<0.001).

Conventional caries detection methods

As shown in Table 2, the most commonly used methods for caries detection were visual-tactile using an explorer and air drying (255, 86.6%) and digital radiography (228, 77.6%). The majority of respondents never use microscopic magnification (268, 91.1%) or tooth separation with impression (277, 94.2%). Only 39.8% (n=117) always cleaned the fissure system before the examination. The main reasons given for preferring one method over another were perceived effectiveness (77.9%) and efficiency (64.3%). The availability and affordability of the devices was also noted by some as influencing their choice of method.

Technology-based caries detection techniques and devices

The respondents' awareness of these diagnostic devices is shown in Figure 1. The majority of respondents were aware of both transillumination (281, 96%) and DIAGNODent (277, 94%). Only 65% were aware of FOTI, while between 5% and 30% were aware of the other devices. Although males were generally more aware of the modern caries detection devices, no statistically significant gender differences were found.

The majority of respondents did not own or have access to most of the modern detection devices including FOTI, DIFOTI, QLF, ECM, EIS, OCT and ultrasound. Transillumination was the most commonly owned device (72.9%), followed by DIAGNODent

Table 2. Use of conventional caries detection methods (brackets contain row percentages unless otherwise indicated).

	Never	Rarely / Seldom	Often / Always
Explorer	82 (27.9)	115 (39.1)	97 (33.0)
Explorer and air drying	5 (1.7)	34 (11.5)	255 (86.8)
Cleaning the fissure system	35 (11.9)	142 (48.3)	117 (39.8)
Magnification using loupes only	127 (43.2)	63 (21.4)	104 (35.4)
Magnification using loupes with attached light	147 (50.0)	41 (14.0)	106 (36.0)
Magnification using microscope	268 (91.1)	12 (4.1)	14 (4.8)
Intraoral camera	155 (52.7)	73 (24.9)	66 (22.4)
Conventional radiographs	180 (61.2)	22 (7.5)	92 (31.3)
Digital radiographs	51 (17.3)	15 (5.1)	228 (77.6)
Separation technique	209 (71.1)	82 (27.9)	3 (1.0)
Separation with impression technique	277 (94.2)	17 (5.8)	0 (0.0)

Table 3. Use of modern detection devices (brackets contain row percentages unless otherwise indicated).

	Never	Rarely / Seldom	Often	Always
Transillumination	9 (3.1)	87 (29.6)	104 (35.4)	14 (4.8)
DIAGNODent	22 (7.5)	52 (17.7)	35 (11.9)	15 (5.1)
Fibre-Optic Transillumination (FOTI)	4 (1.4)	42 (14.3)	24 (8.2)	1 (0.3)
Digital Fibre-Optic Transillumination (DIFOTI)	1 (0.3)	6 (2.0)	2 (0.7)	2 (0.7)
Quantitative Light-induced Fluorescence (QLF)	2 (0.7)	4 (1.3)	1 (0.3)	0 (0.0)
Electronic Caries Monitor (ECM)	2 (0.7)	2 (0.7)	1 (0.3)	0 (0.0)
Electrical Impedance Spectroscopy (EIS)	1 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)
Optical Coherence Tomography (OCT)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Ultrasound	1 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)

Note: Total percentages may be less than 100% as these figures apply only to dentists with access to devices.

(42.2%). Use of these devices is shown in Table 3. In spite of the relatively high availability of DIAGNODent devices, more than half of those with access did not report using this method of caries detection regularly. When asked about their views on individual detection devices (see Table 4), transillumination was described as easy to use (77.2%) and efficient (55.8%), but only 28.6% described it as trustworthy. Fewer respondents found DIAGNODent easy to use (49.7%) or efficient (33.7%), with only 21.4% considering it trustworthy. When compared with transillumination, DIAGNODent was described by a larger percentage of respondents as expensive (5.1% vs. 34.7%%) and requiring high maintenance (1.0% vs. 9.5%). Some respondents also commented that they thought DIAGNODent is "unreliable", "not always accurate as it often gives false positives" and it "has a hocus pocus reputation". With regards to the remaining devices, most respondents were unfamiliar with them and therefore did not comment further. The majority of respondents (241, 82.0%) would not be put off buying any of the devices because of bad reviews, although a small percentage (14.3%) felt that they would not buy the DIAGNODent device for this reason.

DISCUSSION

Over the past few decades, a wide range of technology-based caries detection methods has been developed. The aim of this study was to explore methods used by New Zealand dentists to diagnose caries, their awareness and opinions of newer technologies and their frequency of use of all detection methods. To our knowledge, only two previous publications are available that report on caries detection methods. As both were limited to the same DPBRN (Rindal et al., 2010; Gordon et al., 2011), their findings may not reflect the views of the average GDP not involved in research. In addition, no study of New Zealand GDPs and their caries detection methods has been published to date.

One limitation of this study was that some of the socio-demographic characteristics of the respondents differed from those of the New Zealand GDP population. Proportionally more respondents were not in private practice than in the general dentist population of NZ. However, with regards to both gender and country of graduation, the number of respondents was representative. Although the external validity of the observations was affected, the internal validity was reasonable. It was of interest that the more recent graduates and younger dentists were less likely to have participated. The authors had expected a greater response from this demographic group as they have grown up in a world surrounded by technology and are both fluent and comfortable with it. A second limitation was the low response rate. It has been found, however, that online surveys are far less likely to achieve a response rate comparable to postal surveys (Jones and Pitt, 1999; Leece et al., 2004; Kongsved et al., 2007). Our response rate of 28.6% did, however, fall within the expected 25-30% rate from an email survey (Kittleson, 1997) and was within the parameters reported by other dental-related online studies (Aitken et al., 2008; Lee et al., 2009; Bird et al., 2009; Kiolbassa et al., 2011).

The results of this study show that, while individuals may have their own preferences for detecting caries, the majority of New Zealand GDPs are using conventional visual-tactile methods and digital radiography. This finding is in agreement with the DPBRN study which reported that visual examinations and radiographs are still commonly practiced by dentists on a daily basis (Rindal et al., 2010). As it has been shown that incipient caries, such as white spot lesions, can be seen more clearly if the tooth surface is dried before examination (Pretty, 2006), it was pleasing to see that the majority of respondents used an explorer with air drying rather than an explorer alone. Unfortunately though, the majority of respondents rarely or never clean the teeth before carrying out a caries examination.

Separation of teeth in order to visually assess the approximal surface can be a good supplementary tool in caries detection (Hintze et al., 1998). The amount of separation achieved, particularly in the permanent dentition, is often limited which affects direct visual access. An impression can be taken

Table 4. GDP's views on modern detection devices (brackets contain row percentages unless otherwise indicated).

	Easy to use	Efficient	Trustworthy	Expensive	High maintenance	Latest device	Unfamiliar with device
Transillumination	227 (77.2)	164 (55.8)	84 (28.6)	15 (5.1)	3 (1.0)	2 (0.7)	57 (19.4)
DIAGNODent	146 (49.7)	99 (33.7)	63 (21.4)	102 (34.7)	28 (9.5)	4 (1.4)	78 (26.5)
FOTI	74 (25.2)	64 (21.8)	39 (13.3)	24 (8.2)	3 (1.0)	3 (1.0)	197 (67.0)
DIFOTI	17 (5.8)	12 (4.1)	12 (4.1)	25 (8.5)	5 (1.7)	9 (3.1)	258 (87.8)
QLF	6 (2.0)	5 (1.7)	1 (0.3)	19 (6.5)	2 (0.7)	2 (0.7)	265 (90.1)
ECM	6 (2.0)	4 (1.4)	3 (1.0)	16 (5.4)	3 (1.0)	1 (0.3)	269 (91.5)
EIS	0 (0.0)	1 (0.3)	0 (0.0)	9 (3.1)	3 (1.0)	3 (1.0)	278 (94.6)
OCT	1 (0.3)	2 (0.7)	1 (0.3)	11 (3.7)	0 (0.0)	3 (1.0)	279 (94.9)
Ultrasound	1 (0.3)	1 (0.3)	1 (0.3)	15 (5.1)	2 (0.7)	4 (1.4)	272 (92.5)

Note: Total percentages may be more than 100% as several options could be chosen.

to establish the presence, or absence, of cavitation (Pitts and Rimmer, 1992; Hintze et al., 1998). Separation with, or without, an impression was a method used by very few respondents. The need for a time-consuming follow-up visit after placement of the separating elastic may be considered a barrier to its use (Pitts, 2001). In NZ, dentists are not remunerated for the time involved in using this technique for patients who are being treated under the government-funded Adolescent Oral Health Scheme. As dentistry for most other groups is privately funded, this visit would incur an extra cost for the patient, but could prevent unnecessary surgical intervention and its associated long-term sequela for the tooth.

Digital radiographs have many advantages over conventional radiographs such as reduced working time, imaging enhancement and processing, lower levels of radiation for the patient, and ease of duplication (Yang and Dutra, 2005; Pretty, 2006). In a randomized survey of 800 New Zealand dentists carried out in early 2012, it was found that 58.0% of respondents were using digital radiography (Ting et al., 2013). As this number has undoubtedly increased over the past 3 years, it is not surprising that over three-quarters of the respondents reported routinely using this method of caries detection.

Although it has been suggested that magnification loupes lead to improve accuracy and their use in caries detection is recommended (Forgie et al., 2002), a study by Mitropoulos et al. (2012) showed that enhanced and unenhanced vision achieved comparable values of sensitivity and specificity when detecting occlusal caries. When diagnosing the first visual changes in enamel (International Caries Detection and Assessment System code 1 lesions), magnification actually resulted in lower agreement between examiners than unaided vision. While this could lead to the false-positive diagnosis of non-carious surfaces, these early lesions are fortunately managed with a preventive and not a surgical approach. It has been shown that the use of magnification changes restorative decision-making behaviour. Whitehead and Wilson (1992) found that the number of defects observed and considered to warrant operative intervention increased considerably when magnification was used. Although less than three-quarters of the respondents in our study indicated that they use loupes (with or without attached illumination) on a regular basis, this was higher than the 30.4% reported in a United Kingdom study (Chadwick et al., 2007) and the 40% in the DPBRN study (Gordon et al., 2011).

Taking into consideration the disadvantages of loupe use for caries detection, it is perhaps fortunate that very few dentists in our study reported using an operating microscope with even higher magnification for this purpose. Not only are they expensive to purchase and take up considerable clinic space, the operating microscope at 16x magnification has been shown to make no statistically significant difference to correct diagnosis compared to unaided visual examination (Erten et al., 2006; Akarslan and Erten, 2009).

A significant increase in the probability of making a correct diagnosis has been attributed to the use of intraoral cameras (Forgie et al., 2003; Erten et al., 2006). Erten et al. (2006) thought that this device helped the observers to assess the absence, presence and extension of the caries more accurately compared to the other methods used in their study, namely unaided visual examination and the operating microscope. Both affordability and availability were mentioned by several respondents in the current survey as important factors influencing their choice of caries detection method. This may partly explain why only 22.4% of respondents use this tool. In addition, as with all new techniques, the use of intraoral cameras requires proper training in order to achieve the best possible accuracy (Forgie et al., 2003). As the DPBRN study did not explore this technology, no comparison can be made. However, a recent study on the use of digital technologies by dentists in the Netherlands found intraoral cameras were used daily/weekly by 26.1% of respondents (van der Zande et al., 2015). No information was given regarding the reasons for their use.

In agreement with findings reported in the DPBRN study, FOTI and laser fluorescence are not commonly used diagnostic tools in NZ. FOTI was, however, perceived by several respondents

as being easy to use and efficient, a view confirmed by Pretty (2006) who describes it as economical, not time consuming and having a short learning curve. The inability to store images has been addressed in development of the DIFOTI device. Respondents in our study seldom used this device.

Non-fibre optic transillumination and DIAGNODent were the most commonly used "modern" detection devices used by the New Zealand respondents. It would appear that more of this group used the DIAGNODent than their DPBRN counterparts, although numbers and percentages in the latter study were reported by lesion location making comparisons difficult (Gordon et al., 2011). DIAGNODent has the advantages of being relatively inexpensive when compared with the other new devices (Pretty and Maupome, 2004), increasing the dentist's capability to confirm the presence of incipient caries, and recorded readings for longitudinal monitoring of the effectiveness of non-invasive interventions (Pretty and Maupome, 2004). Unfortunately, false positives are common as readings can be altered by the presence of plaque, calculus and staining (Yang and Dutra, 2005; Pretty, 2006; Amaechi, 2009), areas of hypoplasia or irregular anatomic characteristics (Yang and Dutra, 2005).

While plaque and calculus deposits on a tooth can affect DIAGNODent readings, this is not the only caries detection method where cleaning of the teeth prior to assessment should be routinely carried out. All diagnostic techniques, whether visual or technology based, necessitate a clean tooth. As just under 40% of participants in this study reported cleaning the fissure system often/always, inclusion of this important step into the examination protocol of all GDPs could help to improve their diagnostic skills and accuracy.

The majority of respondents were unfamiliar with DIFOTI, QLF, ECM, EIS, OCT and ultrasound. As the evidence supporting many of these devices is still limited, this may be a barrier to their acceptance. The diagnosis of fissure caries has always been recognised as difficult with a high portion of over-registrations and inconsistencies shown to occur among dentists (Nytun et al., 1992). Even under ideal visual examining conditions in a laboratory, only 48.7% of lesions that had penetrated to dentine were detected (Ricketts et al., 1993). However, combining these newer technologies with traditional methods may improve GPD's decision making and their ability to follow-up on lesion activity over time.

CONCLUSION

Despite the wide range of caries detection devices available, the most commonly used diagnostic methods for caries detection among New Zealand GDPs remain use of the explorer, air drying, and digital radiography. Although transillumination and the DIAGNODent are used by some, the majority of respondents are unfamiliar with most of the newer technology-based devices. It would be of interest to revisit this topic in the future to explore any changes.

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