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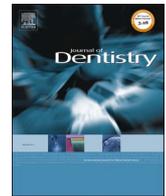
The utilisation of teledentistry in Australia: A systematic review and meta-analysis

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ABSTRACT

Background: Teledentistry is the usage of information-based technologies to deliver healthcare services remotely. It is used to deliver care in regional, rural and remote regions and was particularly useful to deliver care during the COVID-19 pandemic.

Objective: This systematic review and meta-analysis aimed to determine teledentistry utilisation in Australia.

Methods: The databases PubMed, Google Scholar, EMBASE and Web of Science were searched from inception to June-2024. The phrases "Dental" AND "Telehealth" AND "Australia" and "Teledentistry" AND "Australia" were used. Two authors completed the study selection and data extraction. The Joanna Briggs Institute Critical Appraisal Tools were used to assess quality and bias.

Results: Eighteen articles met the inclusion criteria. There were six diagnostic tests, six cross-sectional studies, 4 economic evaluations, one qualitative study and one expert opinion. Teledentistry was accurate for screening caries (average sensitivity=69.7 %, average specificity=97.4 %). There also appeared to be a non-significant negative correlation between specificity and sensitivity ($r = 0.432$). Opinions regarding teledentistry were mixed from clinicians but positive from patients. Teledentistry may also lead to savings for patients and healthcare providers.

Conclusion: Teledentistry increases healthcare access especially for people in regional, rural and remote areas. It is an effective screening tool for caries. Whilst the opinions of clinicians were mixed, potential implementation barriers were identified which could improve opinions of clinicians and increase implementation.

Clinical Importance: This study demonstrates teledentistry as a satisfactory tool for screening caries. This could be beneficial to those with difficulties visiting dentists in-person, particularly if they live in regional, rural or remote areas.

1. Introduction

Telemedicine is "the use of information-based technologies to deliver healthcare across geographic distances" [1]. When telemedicine is used in the dental field, it is known as teledentistry [2]. Extensive technological advances with improved computers, telecommunication technology, diagnostic imaging, and software have made teledentistry more accessible for clinicians and patients [3]. This has allowed for improved patient management, including access to general and specialist care from thousands of kilometres away [2]. Teledentistry involves networking, sharing digital information, distant consultations, electronic prescriptions, workups, and analysis [2]. It can be used for long-distance triages and consultations. Teledentistry also allows live interactions between clinicians and patients to provide advice, however it can also be used between clinicians for support and education [4]. It has also been utilised previously to provide simple treatment such as the prescription of antibiotics [5]

Telemedicine can be broadly split into 3 categories: synchronous, asynchronous and remote monitoring [2]. Synchronous telemedicine delivers health services in real-time, allowing for live discussion between patients and healthcare workers. For example, when a patient and medical worker communicate between distant sites. Synchronous

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telemedicine also refers to appointments where a facilitator, for example, a nurse, medical assistant, etc., gathers information using equipment to transmit to a provider who is at another location [6]. Asynchronous telemedicine is also called the "store and forward technique". This involves a patient or physician collecting information such as the medical history, images, and pathology reports and sending them to a specialist who provides a diagnosis or treatment advice. This service is not provided in real-time [6]. The third type of telemedicine is remote monitoring. This is when a patient is continuously monitored through live video streaming or regular review of remotely collected tests and images [6].

To our knowledge, systematic reviews of the usage of teledentistry in Australia have yet to be conducted since the COVID-19 pandemic, which is essential to explore, mainly as teledentistry usage changed and increased during the pandemic [7]. It is essential to research the usage in Australia as our health system is unique in that there are both public and private clinics and private health insurance that reimburse patients after treatment. In Australia, item codes are assigned to specific treatments, which can then be used to charge patients so their insurers can reimburse them. This may influence patient behaviour as they are more likely to seek treatment from their dentist if there are higher reimbursements received from their private health insurer, and this can also influence the type of treatment offered by clinicians. For example, in Australia, patients with private health insurance had a higher number of medical specialist visits (0.52 vs 0.47, $p < 0.05$) and were more likely to utilise preventive care such as breast screening (0.20 vs 0.14, $p < 0.05$) [8]. It is important to note, however, that these findings were from studies that did not analyse the usage of dental services. Before the pandemic, teledentistry was not offered regularly. However, the usage increased after the introduction of new teledentistry codes, which may be due to clearer guidelines for patients and clinicians regarding teledentistry and billing [7]. Therefore, it is important to analyse usage patterns in Australia as they may differ from other countries.

Previous studies have been conducted analysing the global utilisation of teledentistry. For example, teledentistry has been shown to be an effective means for dental referral, treatment planning and compliance [9]. Additionally, another study demonstrated that there was no significant difference between traditional clinical examinations and teledentistry-based checkups for detecting dental caries [4]. However, as previously mentioned, due to the differences in the Australian healthcare system, it is still important to analyse Australian utilisation of teledentistry.

The main objective of this systematic review was to analyse the utilisation of teledentistry in Australia.

2. Methods

This systematic review followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRIMSA) guidelines [10]. A literature review was conducted to analyse the use of teledentistry in Australia specifically. This review was registered with PROSPERO (Registration number: CRD42024558499)

2.1. Inclusion/exclusion criteria

Using the PICO strategy, the studies that met the following criteria were included in the study.

- Population – Australians utilising teledental services
- Intervention – Utilisation of teledentistry to provide care such as consultations, examinations, emergency triage and prescriptions
- Control/Comparison – In-person consultations, examinations, triage and treatment
- Outcome – Sensitivity and specificity, acceptability, utilisation and reliability of teledentistry

The inclusion criteria were any studies conducted on teledentistry in Australia, and the exclusion criteria were any studies not conducted in Australia, non-extractable data, full text not available and multiple publications of the literature. Australia was chosen as the country of interest as the healthcare systems of each country are different making comparisons between different countries difficult.

2.2. Data sources and retrieval strategies

The research strategy was developed and implemented according to PRISMA. The databases of PubMed, Google Scholar, EMBASE and Web of Science were searched using the terms "Dental" AND "Telehealth" AND "Australia" as well as "Teledentistry" AND "Australia". Google Scholar was also manually searched to see if any additional articles were able to be found. Articles published before June 2024 were analysed. Outcomes were not predetermined prior to conducting the search.

2.3. Data collection and extraction

Duplicate data was removed using EndnoteX9 (Philadelphia, PA, USA) after which two authors (JL and BF) independently analysed the title, abstracts and dull texts. Any differences were discussed with a third author (JSP). Relevant data including country, type of study, multi or single centre, number of participants and number of teeth (if applicable) was extracted. For caries diagnosis studies, number of teeth assessed, percentage of unrateable teeth, sensitivity and specificity was also extracted. From these studies, both qualitative and quantitative data were extracted.

2.4. Quality and bias assessment

The risk of bias and quality was assessed using the Joanna Briggs Institute critical appraisal tool (JBI) by two authors (JL and BF). This tool was chosen as qualitative, quantitative, and mixed method studies that could be analysed [11-14]. Each study was evaluated, and a score was assigned based on the criteria that were met for each study design; for example, a study met 60 % of the criteria if it met 6 out of 10 criteria.

2.5. Statistical analysis

A meta-analysis was conducted to calculate the specificity and sensitivity of diagnosing dental caries using extra-oral photographs. The average was calculated, and the median value was used when a range was given. Furthermore, sensitivity and specificity were charted on a graph and a linear regression analysis conducted to calculate the r-score using Jupyter Notebook.

3. Results

3.1. Overview

A total of 1021 articles were found after the systematic search. A total of 18 articles were determined to be relevant after sorting by title, abstract and full text. Percentage of agreement between the researchers for title was 96.4 % (Cohen's Kappa 0.92), abstract was 98.8 % (Cohen's Kappa 0.98) and full text was 100 % (Cohen's kappa 1). The articles were restricted to studies on Australian populations only as the review analysed Australian dental practitioners' usage of teledentistry. The search results and exclusions can be seen in Fig. 1.

3.2. Characteristics of included studies

There was a total of 18 studies [15-32]. All studies were from Australia and the detailed characteristics of the included studies are shown in table 1.
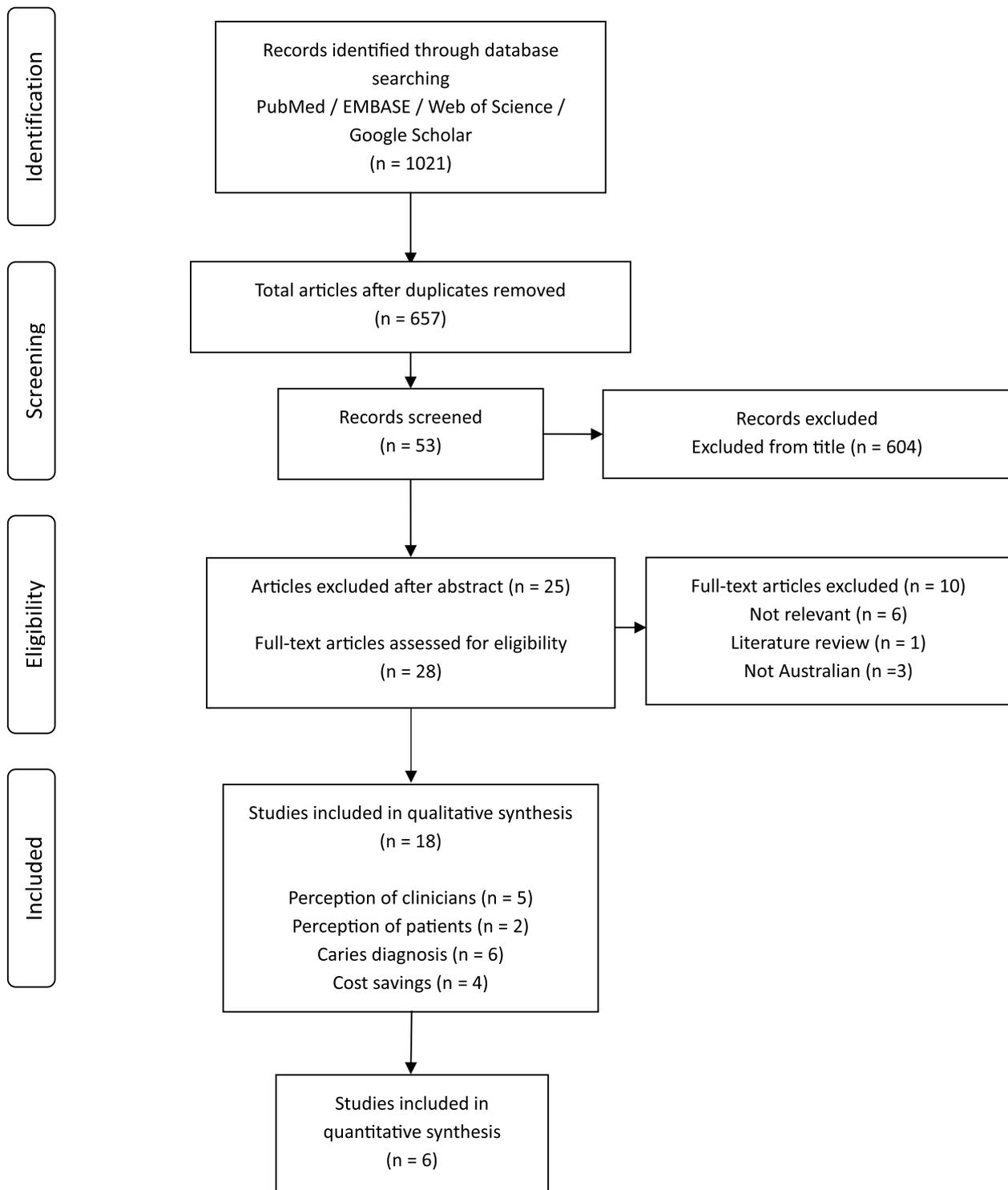
Fig. 1. Process of data collection in accordance with the PRISMA statement for systematic reviews.

3.3. Risk of bias

The 18 articles were assessed for quality using the JBI critical appraisal tool. No studies were excluded based on quality. The quality assessment tables can be seen in Tables 2–6. The diagnostic tests had an average score of 78 % which suggests that the bias was low and quality high. The cross-sectional studies had an average score of 87.5 %. Although it was high, the biggest concern was regarding the identification of confounding factors that could potentially influence practitioner's opinions of teledentistry. Confounding factors are the presence

of some differences between comparison groups, for example between in-person and teledentistry and since the clinicians' experience of tele-dentistry could vary, if these factors are not identified the results could become biased. Only 2 studies identified confounding factors and developed strategies to deal with these factors [15,25]. Economic evaluation studies had an average score of 68 % and this was mainly due to the costs of teledentistry being estimated leading to uncertainties and bias being introduced into the results. The expert opinion article had a score of 67 % due to the source of the opinion not being clearly stated. The qualitative study had a score of 80 %.

Table 1
Characteristics of included studies.

Author/ Year	Title	Country	Study Type	Multi or single-centred	Number of Participants	Number of Teeth
Estai et al. 2016a	Validity and reliability of remote dental screening by different oral health professionals using a store-and forward telehealth model	Australia	Diagnostic test study	Single	126	4032
Estai et al. 2016b	The efficacy of remote screening for dental caries by mid-level dental providers using a mobile teledentistry model	Australia	Diagnostic test study	Single	100	3200
Estai et al. 2016c	A proof-of-concept evaluation of a cloud-based store-and-forward telemedicine app for screening for oral diseases	Australia	Diagnostic test study	Single	30	192
Estai et al. 2017	Comparison of a Smartphone-Based Photographic Method with Face-to-Face Caries Assessment: A Mobile Teledentistry Model	Australia	Diagnostic test study	Single	100	3200
Estai et al. 2022	Mobile photographic screening for dental caries in children: Diagnostic performance compared to unaided visual dental examination	Australia	Diagnostic test study	Single	138	3105
Park et al. 2019	Comparing the outcomes of gold-standard dental examinations with photographic screening by mid-level dental providers	Australia	Diagnostic test study	Single	77	2156
Azimi et al. 2023	Experience of primary caregivers in utilising an mHealth application for remote dental screening in preschool children	Australia	Cross-sectional analysis	N/A	42	N/A
Estai et al. 2016d	Perceptions of Australian dental practitioners about using telemedicine in dental practice	Australia	Cross-sectional analysis	N/A	144	N/A
Estai et al. 2017	End-user acceptance of a cloud-based teledentistry system and Android phone app for remote screening for oral diseases	Australia	Cross-sectional analysis	N/A	22	N/A
Lee et al. 2021	The use of telehealth during the coronavirus (COVID-19) pandemic in oral and maxillofacial surgery – A qualitative analysis	Australia	Cross-sectional analysis	N/A	20	N/A
Lin et al. 2022	A Teledentistry Pilot Study on Patient-Initiated Care	Australia	Cross-sectional analysis	N/A	489	N/A
Tsai et al. 2023	Effectiveness of telehealth in providing preventive oral health care: A pilot evaluation of patient, carer, and clinician experience	Australia	Cross-sectional analysis	Single	37	N/A
Mahony et al. 2023	Dental clinicians' perceptions on the use of tele-dentistry consultations during COVID-19 within public dental clinics in Sydney, Australia	Australia	Qualitative study – Focus groups	Multi-centred	12	N/A
Estai et al. 2018	Cost savings from a teledentistry model for school dental screening: an Australian health system perspective	Australia	Economic Evaluation	Single	N/A	N/A
Marino et al. 2016	Cost-analysis of teledentistry in residential aged care facilities	Australia	Economic Evaluation	Single	100	N/A
Teoh et al. 2018	Economic Evaluation of Teledentistry in Cleft Lip and Palate Patients	Australia	Economic Evaluation	Single	367	N/A
Tynan et al. 2018	Integrated approach to oral health in aged care facilities using oral health practitioners and teledentistry in rural Queensland	Australia	Economic Evaluation	Multi	N/A	N/A
Estai et al. 2016e	Challenges in the uptake of telemedicine in dentistry	Australia	Expert opinion	Unknown	Unknown	N/A

Following the search, the articles were broadly categorised into five categories. Caries diagnosis, the perception of clinicians, patients, cost savings, and benefits/barriers. The caries diagnosis was calculated using the studies' specificity and sensitivity. The results were homogeneous since all the studies were conducted using a similar methodology.

3.4. Perception of clinicians

Five studies were conducted to analyse the opinions of Australian clinicians regarding teledentistry. These were all retrospective analyses utilising questionnaires to determine clinicians' perceptions. Estai et al. [20] analysed the acceptance of a specific Android app used to screen patients for remote diseases through teledentistry. This study analysed the opinions of the people using the application to upload the photographs and the clinicians who downloaded and screened the images. For the users of the application, the overall perception was positive, with 87 % stating that they had their needs met through the application. Additionally, 87 % said the information was clear, 73 % said the app was user-friendly, and 60 % stated the application was easy to use. However, approximately 80 % had negative perceptions of the technology as they faced technical difficulties or system crashes. For those grading the images, 80 % of the participants were satisfied with the application. Approximately 60 % were positive regarding the ease of use and the image clarity to accurately assess the teeth. However, 100 % of the participants noted they had technical problems or crashes [20]. A significant limitation of this study is the sample size, which was only 20. This needs to be higher and, therefore, limits the generalisability of the study. Furthermore, the application is specific and no longer available;

therefore, we cannot identify what the application was capable of. Additionally, technology has improved significantly since 2015, especially the quality of cameras, as many people carry their smartphones [33]. Therefore, the opinions of clinicians may have changed with this improvement.

Another questionnaire conducted in 2016 by Estai [22] and colleagues analysed the opinions of dental practitioners regarding teledentistry. Regarding the usefulness of teledentistry for clinical practice, 96 % agreed that it would enhance clinical training and education, and 72 % agreed that it would provide adequate diagnostic information. Regarding usefulness for patients, 74 % of the participants agreed that teledentistry would save money for the patient, 81 % agreed that it would improve communication with patients, 90 % agreed that teledentistry would be helpful for patient education, 82 % agreed that it would be convenient and well received by patients and 99 % agreed that teledentistry would be beneficial in remote areas [22]. However, concerns were expressed regarding the technology, with 62 % of participants being concerned about the incompatibility between hardware and software, 54 % being concerned regarding the reliability of the technology, and approximately 52 % being concerned regarding the confidentiality of the data sent online [22]. This study had a large sample size of 144, improving the findings' generalisability. Furthermore, it analysed the opinions of both specialist and general dental practitioners. However, the questionnaire did not ask about teledental experience; hence, it is uncertain if the survey respondents had actual teledentistry experience. Additionally, the study was conducted in 2016 and therefore, with improved technology, opinions may have changed. This study demonstrated the benefits of teledentistry including improving access to

Table 2
Diagnostic test studies.

Study	Consecutive or random sample of patients?	Case control design avoided?	Inappropriate exclusions avoided?	Index test results interpreted without knowledge of results of the reference standard?	Was the threshold pre-specified?	Is the reference standard likely to correctly classify the result?	Reference standard results interpreted without knowledge of the index test?	Appropriate interval between index and reference test?	Did all patients receive the same reference standard?	All patients included in analysis?	Total "Yes" responses out of 10
Estai et al. (2016c)	Unclear	Yes	Yes	Yes	NA	Yes	Yes	NA	Yes	Yes	7
Estai et al. (2016a)	No	Yes	Yes	Yes	Unclear	Yes	Yes	NA	Yes	Yes	7
Estai et al. (2016b)	No	Yes	Yes	Yes	Unclear	Yes	Yes	NA	Yes	Yes	7
Estai et al. (2017)	Yes	Yes	Yes	Yes	NA	Yes	Yes	NA	Yes	Yes	8
Estai et al. (2021)	Yes	Yes	Yes	Yes	NA	Yes	Yes	NA	Yes	Yes	8
Park et al. (2019)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	10

Table 3
Analytical cross-sectional studies.

Author	Criteria inclusion clearly defined?	Study subjects and setting clearly described?	Valid and reliable measurement of exposure?	Were the criteria standard and objective?	Were confounding factors identified?	Strategies to deal with confounding strategies stated?	Valid and reliable measurement of outcomes?	Appropriate statistical analysis used?	Total "Yes" responses out of 8
Azimi et al. (2023)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
Estai et al. (2015)	Yes	Yes	Yes	Yes	No	No	Yes	Yes	6
Estai et al. (2016d)	Yes	Yes	Yes	Yes	No	No	Yes	Yes	6
Lee et al. (2021)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
Lin et al. (2022)	Yes	Yes	Yes	Yes	No	No	Yes	Yes	6
Tsai et al. (2023)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8

Table 4
Economic evaluations.

Author	Question well-defined?	Comprehensive description of alternatives?	Important and relevant costs and outcomes for alternatives identified?	Clinical effectiveness established?	Costs and outcomes accurately measured?	Costs and outcomes valued credibly?	Costs and outcomes adjusted for differential timing?	Incremental analysis of costs and consequences?	Sensitivity analyses investigate uncertainty in estimates of costs or consequences?	All issues concerning users identified?	Results generalisable to setting of interest?	Total "Yes" responses out of 11
Estai et al. (2017)	Yes	Yes	Yes	No	Yes	Yes	Unclear	No	No	Yes	Yes	7
Marino et al. (2015)	Yes	Yes	Yes	No	Yes	Yes	Unclear	No	No	Yes	Yes	7
Teoh et al. (2018)	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	8
Tynan et al. (2018)	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	8

care for patients and education and advice for clinicians. It also high-lighted areas of improvement that could be addressed to improve implementation, for example, improving technology and ease of use as well as improving security of the applications to ease the concerns for clinicians regarding privacy.

Azimi et al. [15] analysed the opinions of 42 primary caregivers regarding their usage of teledentistry to diagnose caries in preschool children. They found that overall, the participants perceived tele-dentistry as easy to use and useful [15]. They also found that the ease of use significantly affected the perceived usefulness of teledentistry [15]. Additionally, the attitude towards teledentistry was significantly associated with adopting teledentistry [15]. This meant if they perceived teledentistry in a positive light they were more likely to adopt it which demonstrates that the opinions of clinicians may be a barrier to implementing teledentistry in Australia.

Lee et al. analysed the opinions of Australian clinicians regarding teledentistry in 2021 [25]. This study analysed the perspectives of specialist oral and maxillofacial surgeons relating to their use of tele-dentistry. They found that the participants believed teledentistry was effective for diagnosing simple cases but ineffective at diagnosing more complex cases such as pathology. Teledentistry was convenient for cli-nicians and patients, effective for triaging patients and post-operative reviews, and improved access for rural, regional, and remote patients [25]. However, it was noted that there was a lack of interventional ca-pacity for teledentistry, and there were concerns regarding the reli-ability of the technology [25]. However, this study also has limitations. For example, it was limited to specialist oral and maxillofacial surgeons, limiting its generalisability. Furthermore, there was a limited sample size as it was a qualitative study. However, qualitative research provides a deeper insight into people's perceptions; hence, the small sample size may be a significant manageable limitation [25]. Additionally, they did not ask questions to differentiate between different types of tele-dentistry, making it unclear which type of teledentistry they were studying.

The final study was conducted by Mahony et al. in 2023 [32]. A focus group was conducted to assess dental practitioners' perceptions regarding teledentistry in public dental clinics in New South Wales. Twelve participants were included in this study. They found that all participants found it easy to use and that most patients accepted its usage. Patient acceptance improved as it was used more often and over time. There were frustrations regarding the technology though as the images sent were occasionally of poor-quality making diagnosis diffi-cult. Furthermore, there were large struggles communicating with pa-tients who had limited ability to speak English [32]. However, there were positives. For example, having a template with a list of questions to guide the consult increased efficiency and ease of consults. Teledentistry also improved efficiency of the clinics as patients could be prepped be-forehand regarding what treatment they require and pre and post operative care could be managed using teledentistry as well. It also allowed for more efficient referral of patients to specialist care to improve their outcomes [32]. There were limitations in this study. The focus groups were conducted over video conferences which may have impacted the flow of the conversation. Additionally, the webcams only showed the participants' head and shoulders making body language difficult to read. The study was also only conducted with participants from New South Wales, potentially limiting its generalisability [32].

3.5. Perception of patients

There were two studies that analysed patients' perceptions regarding teledentistry [26,31]. The study by Lin et al. examined the perceptions of 489 patients treated using teledentistry at the Royal Dental Hospital of Melbourne. Approximately 84 % of patients agreed they had a posi-tive experience through teledentistry. Furthermore, 87 % of the partic-ipants agreed that their needs were met, 90 % felt taken care of, and 82 % said they would recommend teledentistry to others [26]. Tsai et al.

Table 5
Textual evidence: expert opinion.

Author	Source of opinion clearly identified?	Opinion source has standing in field of expertise	Central focus of question relevant to the population?	Is the conclusion supported by a logical argument?	Is there reference to the literature?	Incongruence to literature/sources logically defended?	Total "Yes" responses out of 6
Estai et al. (2016e)	No	Yes	Yes	Yes	Yes	No	4

conducted a survey examining factors that could improve perceptions of teledentistry. Of the 37 participants, 97.3 % were satisfied with teledentistry and 81.1 % found that it was an acceptable mode of healthcare delivery. Approximately 56.8 % of the participants felt that teledentistry improved their access to healthcare with only 37.8 % of participants believing that an in-person appointment would have been more effective [31]. The factors that they identified that improve the perceptions of teledentistry were those whose primary language was English and age; participants aged 30–39 found that the quality of the technology was acceptable compared to other age groups [31].

3.6. Caries diagnosis

There were six articles identified for this review assessing the diagnosis dental caries through teledentistry [17-19,21,24,28]. All articles recruited participants to take images of the teeth to be sent to a server for off-site dentists to review. This was asynchronous teledentistry. The teledentistry examination findings were then compared with an in-person examination set as the gold standard. The sensitivity and specificity of the six articles can be seen in the table 7.

The average sensitivity was calculated as 69.7 %, and the specificity was estimated at 97.4 %. For a test to be practical, the sum of the specificity and sensitivity must be 1.5 in total [34]. The studies examined had a sum of 1.67; hence, teledentistry can be an accurate tool to screen for caries.

A linear regression was also conducted to determine if there was a correlation between sensitivity and specificity. The results can be seen in the graph in Fig. 2. It is important to determine the correlation between sensitivity and specificity as they are commonly inversely related in screening tests [35]. In the case of teledentistry, it had a high specificity but low sensitivity. This means a positive diagnosis of caries can be trusted as the rate of false positives is low, however negative results are less reliable. The linear regression showed that there was a negative correlation between specificity and sensitivity which is similar to other screening tests, although the association was weak. This shows that teledentistry can be useful for detecting the presence of caries, however diagnosing whether a tooth is decay free is more difficult through teledentistry.

One of the most significant limitations stated by the authors was the inability to differentiate between photographic artefacts and carious lesions. This may have introduced errors in the results. Additionally, the studies noted that the limitations of cameras were a significant factor as the photos may have been of low quality, increasing the difficulty of diagnosing caries. Furthermore, it is well known that photographs only offer a two-dimensional view of teeth; hence, determining the presence of buccal, lingual or root caries would be very difficult, as well as interproximal decay, a common area for caries to occur [17].

3.7. Cost savings

One of the main benefits of teledentistry is its potential to save on costs, as providing services through teledentistry could be more efficient and reduce travel costs and accommodation. This review identified four articles examining cost savings through teledentistry in Australia. Three of the articles were model-based cost analysis. Estai and colleagues [16] compared the cost of teledentistry to traditional in-person screening for Australian school children. They estimated that 2.7 million screenings

were being conducted in Australia annually. If these oral health screenings were delivered through teledentistry, there would be savings of up to AUD 85 million. They also noted that the technology is scalable, which means that as more screenings are conducted, the cheaper they will become compared to in-person screening [16]. This study only analysed screening for children; hence, it is not generalisable to the adult population. Furthermore, the study only examined the savings from the perspectives of the health system, and although it was not the aim of the study, the potential cost savings to the patients were not considered.

Another model-based cost analysis was conducted by Mariño et al. [27] to compare teledentistry and in-person examinations for residents in aged care facilities in rural Victoria. They predicted that there would be savings of approximately $4.00 per resident [27]. However, this study only examined cost savings from the perspective of aged care facilities. Furthermore, when estimating the costs, items such as the computers and the cost of the internet were omitted, which could lead to inaccuracies in their assessment.

Another model-based cost analysis, conducted in 2017, examined the potential savings from teledentistry consultations for cleft lip and palate. This study compared the cost of patients travelling from rural and regional areas for a standard in-person consultation to teledental consultations at the Royal Children's Hospital in Melbourne. From the hospital's perspective, they estimated that the setup cost would be AUD 2383.61 per year over five years [29]. However, the teledental consultations would save AUD 36.94 per consultation [29]. Many of these savings were attributed to not transporting the patient to the hospital. Additionally, they estimated that 275.3 clinical hours per year could be saved, increasing the capacity of clinicians to see patients and leading to additional increased revenue of approximately AUD 73,400 per year [29]. This study was also the only study to examine the cost savings from the patients' perspective. They estimated savings of approximately AUD 50,258.92 in total, reducing the cost to the patients by 69 % [29]. The main savings to the patient would be travel costs if organising travel themselves and accommodation. The study also found that more timely patient appointments would lead to improved outcomes. Additionally, the further distance a patient lives, the greater the cost savings [29]. This study stated that they had a conservative approach when it came to estimating costs, which may lead to underestimating the true costs, for example, transport or productivity loss. However, even factoring for this, teledentistry still proved to be beneficial. The generalisability of these findings was also low as cleft lip and palate are specific medical conditions, meaning that the study's conclusions may not be applicable to other fields. Furthermore, the Royal Children's Hospital is a tertiary hospital which is quite different from a dental clinic. A flaw of the model analysis studies was that they assumed many variables, such as salaries, travel, and accommodation costs. This introduces bias into the studies as the assumptions may not be accurate. Furthermore, these estimates were conducted in the past, so prices and wages may have changed since then. None of the studies analysed patient acceptance and whether they would prefer to be present in-person or through teledentistry. With healthcare being quite complex, it is important to analyse whether teledentistry can be a substitute for in-person care rather than studying things purely from a cost perspective.

A clinical audit was conducted by Tynan et al. [30] to assess the implementation of a new trial teledentistry program that was used to examine the oral health of residential aged care facilities in rural

Table 6
Qualitative studies.

	Congruity between stated philosophical perspective and research methodology?	Congruity between research methodology and research questions/ objectives?	Congruity between research methodology and methods used to collect data?	Congruity between research methodology and representation and analysis of data?	Congruity between research methodology and interpretation of results?	Statement locating researcher culturally or theoretically?	Influence of researcher on research, and vice-versa, addressed?	Participants and voice adequate represented?	Is there ethical approval?	Do the conclusions drawn flow from the analysis or interpretation of the data?	Total "Yes" responses out of 10
Mahony et al. (2023)	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	8

Table 7
Sensitivity and specificity of the studies assessing diagnosis of dental caries using teledentistry.

Author Details	Number of Teeth Assessed	Percentage of unrateable teeth	Sensitivity	Specificity
Estai et al. 2015 [21]	192 teeth	0 %	57 %	100 %
Estai et al. 2016a [24]	4032 teeth	3.7 %	82–89 %	97 %
Estai 2016b [17]	3200 teeth	11 %	60–68 %	97–98 %
Estai et al. 2017 [18]	3200 teeth	8–19 %	60–63 %	96–99 %
Estai 2022 [19]	3105 teeth	0 %	58–80 %	98.7–99.9 %
Park et al. 2019 [28]	2156 teeth	0 %	61.5 %	95 %

Queensland. The metrics they used were satisfaction and financial impact. They also aimed to identify any areas for improvement. This program utilised oral health therapists to assess the patients at the care facilities, and through the assistance of teledentistry and discussing the clinical information with a dental practitioner, they determined if the patient required an in-person review with the dentist [30]. They found that there were cost savings for patients as out of the 33 patients deemed to require further examination by a dentist, 14 were saved from needing to travel as they were screened online. No adverse events were reported; hence, it could be inferred that teledentistry was accurate in its assessment. The cost of a teledental appointment for the facility was, on average, $241.60 AUD per appointment. The cost of attending in person was approximately AUD 250.60 if the patient was taken by car or AUD 403.80 if taken by ambulance. This means teledentistry saved the facility $9.00 to $162.20 per appointment [30]. The limitation of this study was that it examined the introduction of a trial teledentistry program. Hence, it is difficult to know if the savings will scale with more generalised usage. Additionally, they did not factor in issues such as lost time and productivity by the patients, ambulance transport and attending carers who have to participate in-person appointments with the patient.

3.8. Benefits/Barriers

There was one study conducted by Estai et al. [23] that discussed the benefits of teledentistry and the barriers to implementation. The benefits they identified were divided into four categories: for the patient, care provider, quality of care, and society. The benefits for patients were increased access to care, more timely diagnosis and follow-up for decreased adverse outcomes, improved communications between clinicians and patients, patient education, and the ability to consult remotely with clinicians to avoid travel and accommodation costs [23]. From a care provider's perspective, the benefits were the ability to increase dental workforce capacity, triaging of patients, reduction of waitlists, improved communication and reduced isolation of health professionals working in isolated regions [23]. They also stated that teledentistry can improve the quality of care by increasing efficiency and reducing delayed diagnosis and treatment, which could improve clinical outcomes. From a societal point of view, they stated that teledentistry would minimise the burden on patients and caregivers as less travel time would mean fewer missed work and school days. It could also reduce inequity and inequalities in oral health in the community [23]. The main barriers to implementation they identified individually were poor IT literacy, resistance to new technology, data security and a lack of direct patient contact, limiting the interventional capacity. On an organisational level, teledentistry will be challenging to implement due to incompatibility with already established workflows and systems, lack of reimbursement structure, medico-legal issues and bureaucratic
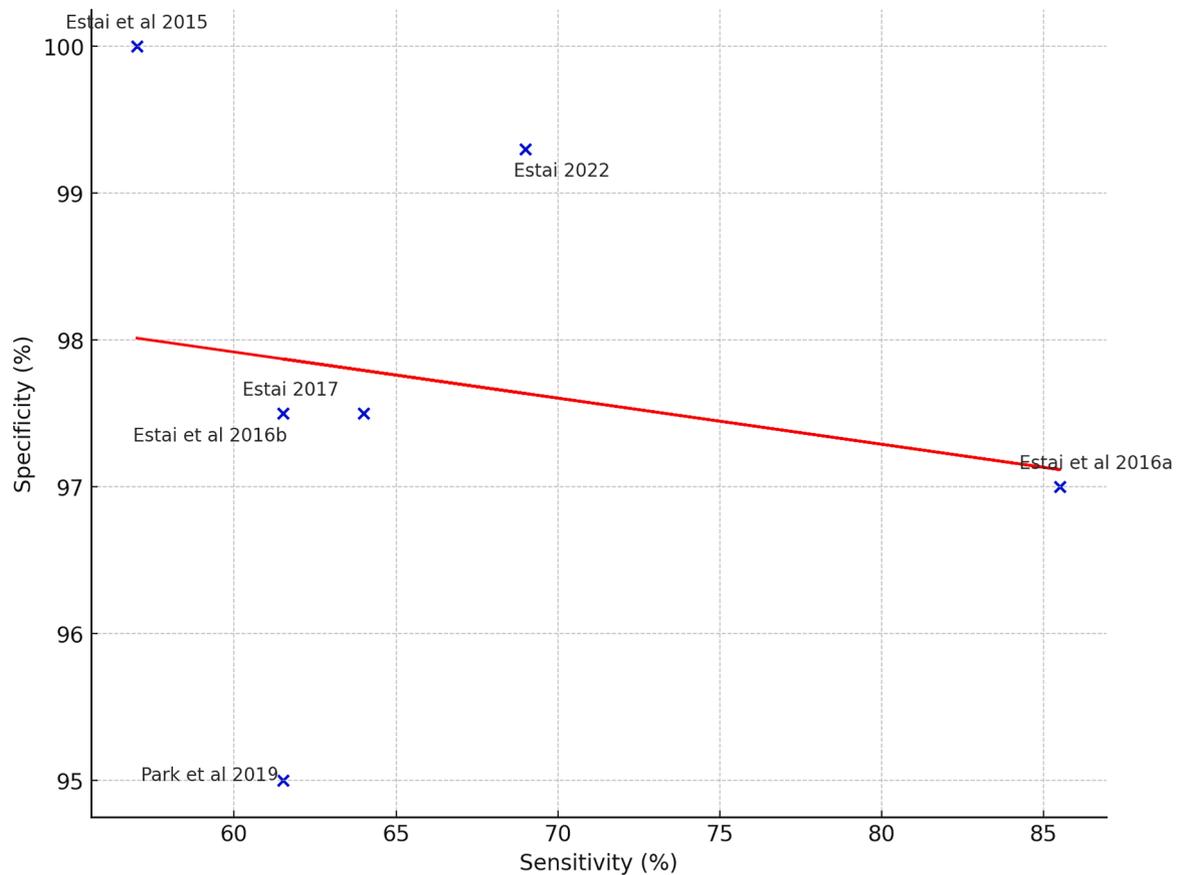
Fig. 2. Linear regression analysis of sensitivity vs specificity: Specificity$= -0.088 \times$ Sensitivity $+ 103.72$ [$r = 0.432$].

difficulties [23]. They also noted that infrastructure may be a limitation, for example, a lack of stable internet connections, hardware and software compatibility, funding, training, and technical expertise [23]. However, this article's methodology was unclear, and it is uncertain how these conclusions were reached as the study design was not listed. This reduces the credibility of the research. The study was also published in 2016, and some of the limitations stated, such as reimbursement, have since been corrected [7].

4. Discussion

This was the first systematic review analysing the usage of teledentistry in Australia, however, there have been studies analysing global utilisation of teledentistry. Furthermore, it was the first meta-analysis calculating the specificity and sensitivity of teledentistry to diagnose caries in Australia. When comparing the findings of the Australian meta-analysis with a previously conducted study, the findings were very similar giving credibility to the results. Priyank et al. [4] demonstrated that there was no significant difference between diagnosing caries through traditional clinical examinations and through teledentistry-based examinations. Together, these findings demonstrates that teledentistry could be a viable tool to diagnose decay. However, the low sensitivity of 69.7 % and high specificity of 97.4 % found in this current study suggests that although positive detection of caries is reliable, a negative result is less so. This is likely because tactile sensation is extremely important to diagnose caries especially in trying to differentiate between staining, hypomineralisation and caries. Therefore, technology needs to be improved in order to overcome this.

Although teledentistry appears to be a promising technology, it has limitations. Large concerns were raised regarding the reliability of the technology, which has been highlighted within the literature regarding

telehealth. Technological infrastructure, concerns regarding privacy and the quality of the technology have all been stated as limitations of teledentistry and barriers to increasing adoption [25,36]. Additionally, patients and clinicians struggled to use the technology. However, this could be rectified through increased education [25].

The clinicians' opinions, in general, were quite mixed in the studies found. These results are similar to global studies. For example, one study found that teledentistry was very useful, particularly during the COVID-19 pandemic and found that early adopters of teledentistry felt that it would have a significant role in the long-term future of teledentistry [37]. However, they noted that many dentists lacked understanding regarding the scope and usefulness of teledentistry, which meant that it would limit adoption [37]. Many dentists were also hesitant to use teledentistry due to ethical concerns and quality of care. Furthermore, concerns were raised about charging patients for teledentistry as they were uncertain regarding the quality of care they could provide through teledentistry [37]. These mixed opinions suggested that whilst teledentistry could be helpful, further education is required for dental practitioners regarding the benefits of teledentistry and how to use it so that it can become more widely adopted. Some barriers to adopting teledentistry were reluctance to invest time to learn a new methodology of delivering care and having a preference for face-to-face as dentistry mainly consists of practical hands-on treatment, meaning virtual appointments have limited usefulness [37]. Difficulties with technology, both using and learning how to use, are also global issues and will be difficult to correct as new technologies are constantly released, making it difficult to understand everything available [38].

The perception of patients regarding teledentistry usage in Australia was found to be quite positive. This is consistent with findings worldwide. Many patients are very positive towards teledentistry, and it has been found that factors such as effectiveness, reliability of the

technology, usefulness and ease of use contributed to this [39]. Additionally, patients with easier access to digital devices were more likely to have positive experiences with teledentistry [40]. This is likely because good infrastructure, such as reliable devices, has been found to be a significant factor in the ease of use [41]. Patients also preferred having the consultation from home rather than travelling to see the clinician in person, especially if the clinician was far away [42]. Additionally, having a consultation from home helped patients with dental anxiety [42]. This could be due to the patient being more comfortable at home, meaning there is a reduced chance of triggering their anxiety. Teledentistry also saved patients' time as they could be discharged from care through teledentistry, reducing the number of in-person appointments required. Conversely, a patient who travels long distances could be confident that a face-to-face appointment was required as they were appropriately triaged through teledentistry [42].

This study found that teledentistry had a high specificity but lower sensitivity. The average sensitivity was 69.7 %, and the average specificity was 97.4 %. As mentioned previously, for a test to be valid, the sum of the specificity and sensitivity must be 1.5 in total [34]. The studies examined had a sum of 1.67 which demonstrates that teledentistry can be an accurate tool to detect dental caries. The accuracy of teledentistry has been studied extensively in the literature. A systematic review analysing the global literature on teledentistry found that for screening caries, the sensitivity ranged from 48 to 100 %, and the specificity ranged from 81 to 98 % [9]. The specificity seemed to have a higher value on average compared to sensitivity, which was similar to the Australian studies as well. Additionally, when teledentistry was used for diagnostic treatment planning, the sensitivity ranged from 81 to 88 %, and the specificity was 82–95 % [9].

The main strength of this study was that it was the first study analysing the usage of teledentistry in Australia. Furthermore, it was the first meta-analysis assessing the specificity and sensitivity of diagnosing dental caries through teledentistry.

However, this study was not without limitations. One of the main limitations regarding the meta-analysis was that the studies involved in assessing the specificity and sensitivity of teledentistry for diagnosing caries were several years old. This meant that the technology used, specifically, the cameras would have been older and hence were lesser quality than more modern cameras. This may have made detecting caries more difficult and affected the results. More studies are required with more modern technology to determine whether there is an improvement. Another limitation of the meta-analysis was the unavailability of the raw data used to calculate the specificity and sensitivity, which may have affected the accuracy of our calculations.

A limitation of the search strategy was that only English articles were reviewed. This could potentially limit the total number of articles we analysed and hence limit our data analysis. Many non-English speaking countries would be utilising teledentistry and publishing data and hence not analysing foreign language publications could limit the generalisability of our findings. However, since this review was analysing the usage of teledentistry within Australia, a country primarily speaking English, we do not expect this to impact our results severely.

The main clinical implication from this study is that teledentistry appears to be a useful tool for oral health screening, especially diagnosing dental caries. It has the ability to increase access to care, particularly for those living in regional, rural and remote areas or those with access difficulties. Early detection of caries would allow for earlier provision of treatment which may prevent hospitalisations due to infections and abscesses. Teledentistry was also acceptable for patients and clinicians, with potential cost savings. Therefore, this systematic review and meta-analysis demonstrate that teledentistry should be implemented on a broader scale in Australia to increase access to dental services.

5. Conclusions

Teledentistry increases healthcare access especially for people in regional, rural and remote areas. This study has demonstrated that it is an effective screening tool for caries with reasonable efficacy. Opinions of Australian clinicians regarding the medium were mixed, particularly due to apprehension regarding the accuracy of the technology. However, barriers were identified that could be overcome to improve clinician opinion and improve adoption. Furthermore, patients in Australia had quite positive views regarding teledentistry.

Ethics approval and consent to participate

This study was conducted according to the ethical principles outlined in the Declaration of Helsinki. Ethics approval was not required as the data is fully available online.

Consent to publish

Not applicable.

Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to protection of the participants' privacy but are available from the corresponding author on reasonable request.

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CRediT authorship contribution statement

Joshua Lee: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Joon Soo Park:** Writing – review & editing, Visualization, Validation, Supervision, Project administration, Methodology, Formal analysis, Conceptualization. **Boxi Feng:** Writing – review & editing, Visualization, Validation, Methodology, Investigation, Data curation, Conceptualization. **Kate N Wang:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Data curation, Conceptualization.

Declaration of competing interest

The authors declare no conflict of interest.

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