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Usage of Chelating Gels in Root Canal Preparation: A Survey of Australian Clinicians

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Abstract: Chelating gels may initially assist in root canal preparations to help establish a glide path. While irrigation surveys have investigated liquid chelators and gels to a minor extent, no endodontic survey has focused on EDTA gels and why clinicians use them. All 395 members of the Australian Society of Endodontology (ASE) were emailed an 11-question survey concerning chelation gel usage via Qualtrics. Paper copies were also distributed at ASE events. Descriptive statistics were performed for practitioner and chelating gel data. Cross-tabulations of the practitioner type with the case percentage usage of gels were analyzed with the chi square test (adjusted p value < 0.0083). The overall response rate was 181/395 (46%). For 174 eligible responses, those who never/rarely used a gel were as follows: endodontic residents 12/14 (86%), endodontists 53/71 (75%), general dentists 39/86 (45%), and other members 0% (0/3). Most gel users said that gels helped establish a glide path. Those who never/rarely used chelating gels commented that they held no benefits over liquid EDTA. Endodontists were less likely to use a chelation gel than general dentists ($p < 0.0083$). Older clinicians had higher gel usage than younger ASE members ($p < 0.0083$), indicating a possible trend to diminished gel usage over time amongst ASE members. In conclusion, most ASE members find no need for a chelating gel, raising questions about their clinical effectiveness. Studies would therefore be warranted to investigate gel efficacy and improved clinical outcomes.

Keywords: cohort effect; EDTA; endodontic chelating gels; endodontic survey; glide path; practitioner usage

Citation: Wright, P.P.; Diamond, E.S.; Peters, O.A. Usage of Chelating Gels in Root Canal Preparation: A Survey of Australian Clinicians. *Oral* **2024**, *4*, 315–324. https://doi.org/10.3390/oral4030026

Academic Editor: Giuseppina Campisi

Received: 22 May 2024
Revised: 23 July 2024
Accepted: 23 July 2024
Published: 26 July 2024

1. Introduction

Ethylenediaminetetraacetic acid (EDTA) is a hexadentate ligand able to stably bind metal ions, including calcium [1]. Because of this phenomenon, aqueous EDTA solutions were introduced into endodontics by Nygaard-Ostby in 1957 to help clean dentin and widen root canals [2]. In this role, EDTA liquid is advocated as a final rinse at the completion of root canal preparation to remove the smear layer [3]. While EDTA liquids and gels both act as canal lubricants [4] and remove the smear layer [5], the best use of gels is in the early stages of root canal preparation for lubrication where they help establish a glide path in canals that are difficult to negotiate [4]. Indeed, gel usage later on in root canal preparation, when rotary instrumentation is employed, is contraindicated due to adverse mechanical effects of the gel on rotary instruments [6]. Thus, the clinical roles of EDTA gels and liquids differ. While an EDTA final rinse carries the warning that dentinal erosion may ensue if the final sodium hypochlorite (NaOCl) rinse is prolonged [7], when a gel is used in the early stages of root canal preparation, some calcium removal may be beneficial in the establishment of a glide path in curved and calcified canals. Gels do result in the loss of dentin, with one study on EDTA chelating gels showing a loss of dentin from root canal slices, with the effect dependent on the exposure time and gel type [8]. Further

advantages of EDTA gels in initial preparation are that they assist with the removal of tissue plugs [9,10], and compared to liquid EDTA, they are reportedly less prone to canal extrusion [11]. Conversely, one disadvantage of some gels is that they contain chemicals incompatible with oxidizing agents [12]. Hence, the concurrent use of NaOCl may pose a problem, and at least one case of subcutaneous emphysema has been reported in the literature following their use [13].

Surveys concerning endodontic irrigation frequently include questions about EDTA chelation. A 2012 survey of American Association of Endodontists members reported that 77% of respondents routinely tried to remove the smear layer, and although 80% used EDTA as an irrigant, the role of a chelating gel was not mentioned [14]. Similarly, a recent irrigation survey in the UK and Ireland reported EDTA usage, but not specifically of EDTA gels [15]. In 2014, a US survey of general dentists stated that that 73% aimed for smear layer removal and that 83% used a gel chelator/lubricant. Again, details of the gels were not reported [16]. A recent Russian survey found that while only 23% used EDTA as a gel, this fraction increased to almost half amongst dentists in government-run clinics [17].

Little is known about the reasons why clinicians use a chelating gel, which groups of practitioners incorporate a chelating gel into non-surgical root canal preparation, and if they are satisfied with the characteristics of the gel they use. Indeed, to the best of our knowledge there has not been a survey focused on chelation gels. Therefore, the aim of the current research was to survey the membership of the Australian Society of Endodontology (ASE) on their usage of chelation gels. The ASE is a group comprised of endodontists (registered specialists in endodontics), general dentists, Doctor of Clinical Dentistry (DClinDent) students in endodontics (endodontic residents), and a small number of other students and veterinary dental practitioners. This survey sought not only to examine differences between various groups of clinicians but also to determine attitudes and barriers to gel usage, why practitioners use them, and if the characteristics of the gel they use were satisfactory. The null hypothesis was that clinicians in all of the ASE member categories, based on practitioner type or experience, would use chelating gels to the same extent.

2. Materials and Methods

2.1. Survey Administration and Design

Only current ASE members over 18 years of age were eligible for the survey. The response from non-practicing practitioners was recorded, but they were ineligible to answer the survey questions. Preliminary questions were sent to a private practice of six general dentists, who all answered the questions and provided further information on their use of chelating gels. A survey was then formulated by one author (P.P.W.) with revision and review by the other authors (O.A.P. and E.S.D.), one of whom had extensively published endodontic surveys. An external general dentist, experienced in survey design, then assessed the survey, making comments and suggestions, which were incorporated into the survey. All authors approved the final design.

The survey was predominantly administered via the online platform Qualtrics. Three emails with the same questionnaire link were sent to all 395 members of the ASE from July to November 2021. Paper copies were also distributed in the first half of 2022, at state meetings and during a federal conference, to ASE members who had not previously responded.

The survey consisted of 11 questions. Skip logic was incorporated into the design to direct participants to the next appropriate question. Question 1 concerned the currency of endodontic practice, while Questions 2–4 centered on demographics concerning gender, the Australian state of ASE membership, and type of practice (specialist, endodontist, or endodontic resident). Questions 5–6 were related to endodontic experience, while Question 7 enquired about limitations on chelator usage. Question 8 asked about the percentage of cases where a chelation gel was used. For those who used a gel, Question 9 asked which gel the participant used, followed by a grid question on participant satisfaction with the properties of that particular gel. The final question sought any further comments.

The survey had an expected response time of 9 min. The survey questions are reproduced in Figure 1.

1. Have you practised root canal therapy in the last 12 months? (a) Yes (b) No
   If you answered 'No' you have completed the survey. Thank you for your participation.
2. How do you identify? (a) Male (b) Female (c) Other
3. Which ASE branch do you belong to? (a) NSW (b) QLD (c) SA (d) VIC (e) WA
4. What category of member are you? Mark all that apply.
   (a) Endodontist (b) General dentist (c) DClinDent student, (d) Other, please specify
5. How many years of experience do you have in performing root canal treatments? Do not include undergraduate training. For endodontists, please include any time as a general dentist.
   (a) 0 − 5 (b) 5 − 10 (c) 10 − 15 (d) 15 − 25 (e) 25+
6. Currently, on average, how many hours a week do you spend either performing or teaching endodontics?
   (a) 0 − 3 (b) 3 − 5 (c) 5 − 10 (d) 10 − 15 (e) 15 − 20 (f) 20+
7. What are the factors which limit your use of chelating agents? Please mark all that apply.
   (a) I have no limitations (b) I find them of little use (c) I worry about adverse effects (d) I was told by an endodontist or mentor not to use them (e) I have insufficient understanding of them (f) Other, please specify.
8. In what percentage of cases requiring canal preparation do you use a chelating gel?
   (a) 0 − 1% (b) 1 − 20% (c) 20 − 40% (d) 40 − 60% (e) 60 − 80% (f) 80 − 100%
   If you answered (a) 0 − 1%, please go to Question 11.
9. Which chelating gel do you prefer to use? (a) FileEze (b) Glyde (c) Odontoprep (d) RC-Prep (e) SlickGel ES (f) Other, please specify.
10. Please check the appropriate boxes labelled 'Yes', 'Sometimes', 'No', 'Unsure', or 'Not applicable' in response to the following questions concerning the chelating gel you prefer to use.

Question	Yes	Sometimes	No	Unsure	Not applicable
Is the gel too runny?					
Is the gel too viscous?					
Does the gel help establish a glide path?					
Does the gel help negotiate curved canals?					
Does the gel help negotiate calcified canals?					
Does the gel help with apex location measurements?					

11. If you have further comments, please add them now. Comments may include factors that would encourage you to use a chelating gel.

Figure 1. List of survey questions. NSW, New South Wales; QLD, Queensland; VIC, Victoria; SA, South Australia; WA, Western Australia.

2.2. Statistical Analysis

Sample size calculations were made using a 5% margin of error, a 95% confidence level, and a recommended maximal variance of 0.25 [18]. A sample size of 195 was representative of the target population under these conditions. For a 6% margin of error, 160 responses were required. Prism 10.0.3 (GraphPad Software, La Jolla, CA, USA) was employed for the graphics. Cross-tabulations and Pearson's chi square tests were performed in IBM SPSS Statistics 29.0.0.0 (IBM Corp., Armonk, NY, USA). *p* values of the cross tabulated data were calculated for post hoc multiple comparisons tests using a published approach for the analysis of contingency tables [19]. This was achieved by squaring the adjusted residuals (z scores) for each cell to convert them into chi square values. These were then transformed into *p* values using the Sig.Chisq function in SPSS. The Bonferroni correction was applied to a *p* value 0.05 to obtain an adjusted value of 0.0083 for a table of 6 cells.

3. Results

3.1. Reponse

A response rate of 181/395 (46%) was recorded. It corresponded to a 95% confidence level and variance of 0.25. A margin of error of 5.3% was calculated using previously reported methods [18]. This was deemed to be an acceptable sample of the ASE membership. Not all ASE members currently practice, and the responses from four non-practicing respondents were excluded. These members were not eligible to advance further in the survey. Additionally, three surveys were not included because of a lack of response clarity, as explained in detail below. The remaining 174 questionnaires were analyzed.

3.2. Respondent Demographics, Practicing Characteristics, Experience, and Chelating Gel Usage Characteristics

Of the respondents, 74% were male and the remainder were female. State affiliations, practitioner type, years of experience in endodontics, hours worked/week in endodontics, gel types used, and case percentage usage of chelating gels are presented in Figure 2. The largest number of responses were from general dentists at 49%, while endodontists accounted for 41% of the sample. A total of 49% of clinicians had practiced endodontics for over 25 years, and 45% spent more than 20 h/week either practicing or teaching endodontics. Of the 70 named gels, the most popular gel was RC-Prep®. It was employed by 44% of gel users, followed by Glyde™ at 31% (Figure 2). The majority of respondents, 60%, used a chelating gel in 0–1% of cases (none or extremely rare usage). Conversely, 18% used a gel for 80–100% of root canal treatments (Figure 2). Responses to this question were validated by reconciling the name of the chelating gel with the comments supplied. It was obvious that some respondents had misinterpreted the question on gel usage because a high case usage percentage was indicated, but no gel name was given. Instead, they named a chelating liquid, such as EDTA-C, and/or they commented that that they used liquid EDTA and not a gel. In 17 cases where the percentage chosen was inconsistent with the written text, the percentage was adjusted, in line with the comments provided. Three responses were not included for any question because it was unclear if a gel, a liquid, or neither was used. All instances of data cleaning were annotated in an Excel (Microsoft 365) spreadsheet and uploaded to UQ eSpace. The link for the spreadsheet is provided in the data availability statement of this article.

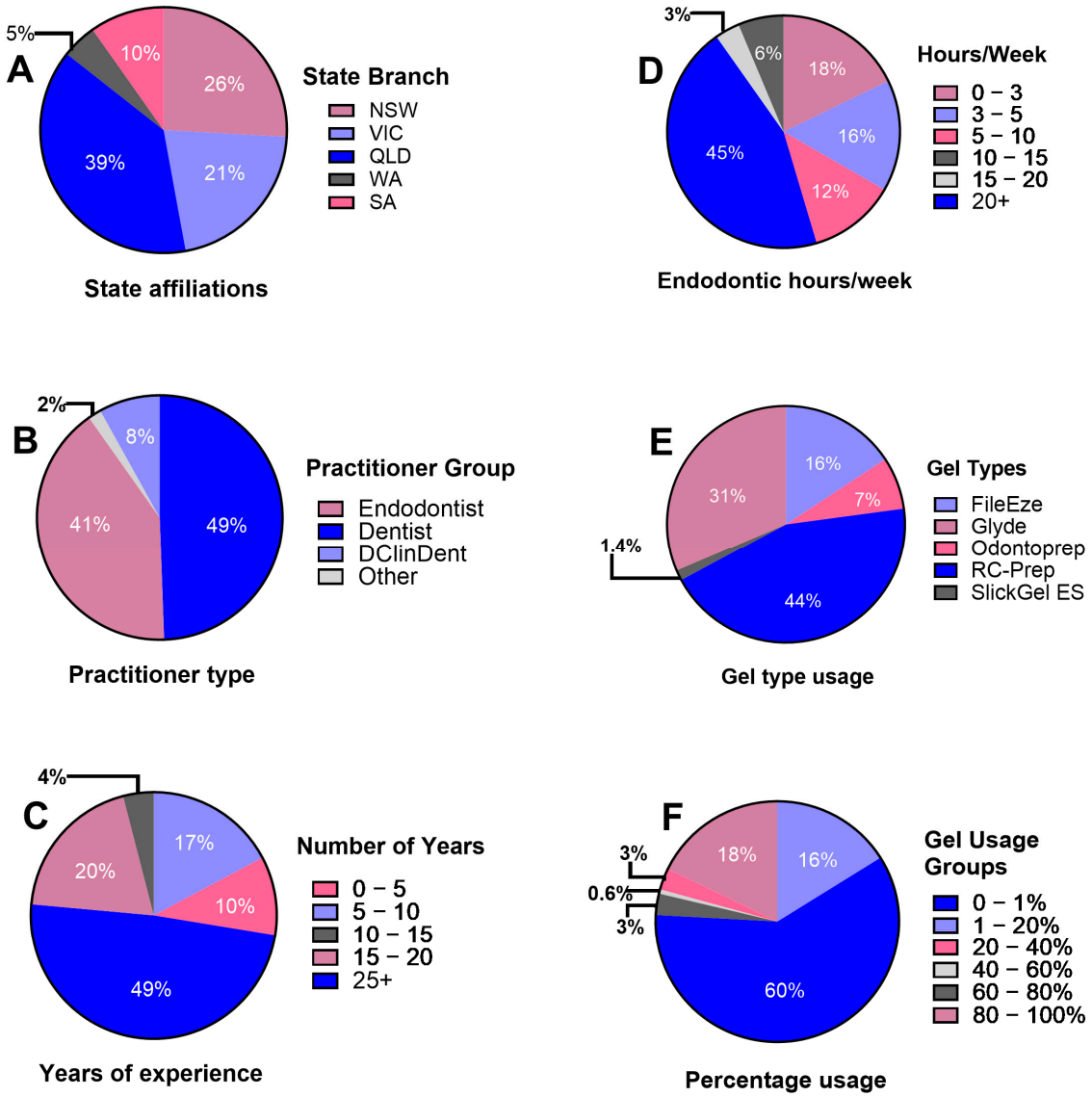

Figure 2. Practitioner demographics, type, experience, and chelating gel usage. (**A**) State branch. (**B**) Practitioner type. (**C**) Years of practitioner experience in endodontics. (**D**) Hours worked/week in endodontics. (**E**) Gel brand used. (**F**) Overall gel usage case percentages. NSW, New South Wales; VIC, Victoria; QLD, Queensland, SA, South Australia; WA, Western Australia.

3.3. Chelaing Gel Usage Patterns

Gel usage percentages were cross-tabulated with all practitioner categories (Table 1A). A high percentage of endodontists and endodontic residents, 75% and 86%, respectively, belonged to the 0–1% usage group, with general dentists scoring lower, at 45%. A Pearson's multiple comparisons chi square analysis was performed on the cross-tabulation of endodontists and general dentists with 0–1%, combined 1–80%, and 80–100% usage categories (Table 1B). Significant differences were recorded between these two clinician groups in the 0–1% and the 1–80% usage categories, with an adjusted $p < 0.0083$. A further cross-tabulation compared older practitioners, with more than 25 years of endodontic experience, to all other practitioner experience groups for the 0–1%, combined 1–80%, and 80–100% usage categories (Table 2). Older practitioners, irrespective of the clinician group, were more likely to frequently use a chelating gel, recording a significantly higher percentage in the 80–100% group ($p < 0.0083$).

Table 1. Cross-tabulations of Clinician Type—Gel Usage Categories. (**A**) Cross-tabulation of endodontist, dentist (general dentist), resident (endodontic resident) and others—all gel usage categories. (**B**) Cross-tabulation of endodontist, dentist (general)—gel usage categories. The "Other" clinician type included two veterinarians and one DMD final year student.

(A)

		Gel Usage Categories						
Clinician Type		**0–1%**	**1–20%**	**20–40%**	**40–60%**	**60–80%**	**80–100%**	**Total**
Endodontist	**Count**	53	6	1	0	1	10	71
	% of endodontists	74.60%	8.50%	1.40%	0.00%	1.40%	14.10%	100%
Dentist	**Count**	39	19	3	1	4	20	86
	% of dentists	45.30%	22.10%	3.50%	1.20%	4.70%	23.30%	100%
Resident	**Count**	12	1	0	0	0	1	14
	% of residents	85.70%	7.10%	0.00%	0.00%	0.00%	7.10%	100%
Other	**Count**	0	2	1	0	0	0	3
	% of others	0.00%	66.70%	33.30%	0.00%	0.00%	0.00%	100%
Total	**Count**	104	28	5	1	5	31	174
	% of clinician type	59.80%	16.10%	2.90%	0.60%	2.90%	17.80%	100%

(B)

			Gel Usage Categories			
			0–1%	**1–80%**	**80–100%**	**Total**
Clinician Type	**Endodontist**	**Count**	53	8	10	71
		Adjusted residual	3.71	−3.02	−1.45	
		***p* value**	0.0002 *	0.0025 *	0.1471	
	Dentist	**Count**	39	27	20	86
		Adjusted residual	−3.71	3.02	1.45	
		***p* value**	0.0002 *	0.0025 *	0.1471	
Total		**Count**	92	35	30	157

An * indicates statistical significance ($p < 0.0083$) in the chi squared multiple comparison analysis.

Table 2. Cross-tabulation of Years of Endodontic Experience—Gel Usage Categories.

			Gel Usage Categories			
			0–1%	**1–80%**	**80–100%**	**Total**
Years of Endodontic Experience	**0–25 Years**	**Count**	60	20	9	89
		% with 0–25 years	67.4%	22.5%	10.1%	100%
		Adjusted residual	2.10	0.02	−2.72	
		***p* value**	0.0357	0.9840	0.0065 *	
	25+ Years	**Count**	44	19	22	85
		% with 25+ years	51.8%	22.4%	25.9%	100%
		Adjusted residual	−2.10	−0.02	2.72	
		***p* value**	0.0357	0.9840	0.0065 *	
Total		**Count**	104	39	31	174
		% of years of experience	59.8%	22.4%	17.8%	100%

An * indicates statistical significance ($p < 0.0083$) in the chi squared multiple comparison analysis.

3.4. Limitations on the Use of Chelating Agents

The question concerning the limitations in the use of chelating agents allowed multiple responses. While just 1% of clinicians worried about adverse effects and 3% had insufficient knowledge of chelating agents, 65% had no limitations on use. About 6% of clinicians had been told not to use chelating agents and 22% found them of little use. The remaining respondents provided a comment on their limitations. Only one clinician specifically

mentioned being limited by the concern that the chemical disinfectant properties of sodium hypochlorite would be diminished when in contact with EDTA.

3.5. Satisfaction with Gel Properties and Usefulness

A total of 70 responses, from all practitioner types, indicated gel use and were eligible for the question on gel viscosity and usefulness (Table 3). The most commonly named viscous gel was RC-Prep. The dentist- and endodontist-only components were examined. The combined yes and sometimes responses for dentists for, respectively, glide path and negotiation of curved and calcified canals were 81%, 68%, and 66%, while for endodontists these respective percentage were 59%, 41%, and 44%.

Table 3. Satisfaction with gel viscosity and usefulness for all practitioner types.

	Yes	Sometimes	No	Unsure	N/A	Total
Is the gel too runny?	0 (0%)	8 (12%)	58 (85%)	1 (1%)	1 (1%)	68
Is the gel too viscous?	5 (7%)	16 (23%)	47 (68%)	0 (0%)	1 (1%)	69
Does the gel help establish a glide path?	27 (39%)	25 (36%)	6 (9%)	9 (13%)	2 (3%)	69
Does the gel help negotiate curved canals?	18 (26%)	21 (30%)	14 (20%)	12 (17%)	4 (6%)	69
Does the gel help negotiate calcified canals?	20 (29%)	24 (34%)	14 (20%)	11 (16%)	1 (1%)	70
Does the gel help with apex location measurements?	3 (4%)	9 (13%)	32 (46%)	16 (23%)	10 (14%)	70

N/A, not applicable.

3.6. Comments

Several comments were received from clinicians who reported a 0–1% gel usage and who were ineligible to answer the grid question concerning gel satisfaction and usefulness. Many in this category commented that they saw no benefit to using a gel over a liquid. Some further explained that their instrumentation was able to deal with the preparation of fine canals, that there was no scientific evidence to support the use of a gel, or that liquids penetrated the dentin better.

Adverse effects were also provided. These included the increased risk of rotary instrument fracture, the accumulation of debris, increased friction, or that a waxy smear layer was left on dentin following gel usage. One respondent further added that a gel needed to be water soluble to avoid the deposition of material on the canal wall. Another commented that they found the apical area harder to clean in the presence of a gel.

4. Discussion

The null hypothesis was rejected because within the ASE, endodontists differed from general dentists, and more experienced members differed from those with fewer years of experience in endodontics. The ASE is a varied group of clinicians with a particular interest in the practice of endodontics. Thus, a survey of its members provides an opportunity to obtain insights into the differential use of chelating gels by clinicians with an interest in endodontics according to practitioner type.

Of the practicing clinicians within the ASE, 60% do not, or extremely rarely, use a chelating gel during root canal preparation. According to the chi square test, this result is attributable to the endodontist component of the membership, while the general dentist component had significantly lower gel usage. Table 1A shows that endodontic residents also had low gel usage. General dentists in Australia lack confidence in treating curved and calcified teeth [20]. Thus, one explanation for their higher usage of gels is that dentists find chelating gels more clinically useful in these situations than endodontists. Indeed, the percentage of dentists who found a gel useful for the creation of a glide path and for the negotiation of curved and calcified canals was higher in each of these sections compared to endodontists. Possibly, the higher skill level of an endodontist lessens the need for a chelating gel. Another possibility is the differential use of dental operating microscopes (DOMs) and loupes. In the United States, the vast majority of endodontists use a DOM, while general dentists predominantly use loupes for magnification [16]. In an endodontic

global survey, which included the use of DOMs, Australian endodontists and postgraduate students made up 85.9% of the Asia–Pacific region where the use of a DOM was 93.6% [21]. Enhanced magnification allows for better canal visualization, and the treatment of canals that are difficult to negotiate may be easier.

Given the low case usage of chelating gels in the current survey, it is worthwhile to review the recommendations of endodontic organizations on the use of chelating gels. In the recent quality standard guidelines of the ASE for nonsurgical endodontic treatment [22], as well as in similar publications of the European Society of Endodontology [23] and the American Association of Endodontists [24], the use of chelation gels is not discussed and no recommendations exist. Hence, chelating gel relevancy may well be questioned. However, while a survey can provide usage patterns, it is not able to provide the scientific evidence needed for a recommendations of use.

A further significant finding of this study was that more experienced practitioners, compared to less experienced ones, used a chelating gel more often. Such an effect is known as a cohort effect. Cohort effects are based on age or period and can incorporate a variety of conceptual frameworks [25]. Cohort effects occur amongst dental practitioners, with one study showing a trend to the higher provision of preventive and diagnostic services by younger clinicians [26]. The current study identified an example of a cohort effect in endodontic practice in Australia. In the UK, a survey of dental schools and general dentists revealed that dentists' irrigation practices tended to increasingly align with teaching practices [15]. The current result may reflect this same phenomenon. That is, dentists' clinical choices are driven by how they were taught and that teaching of chelating gels in Australia has changed over time.

One of the stipulations of the chi square test is that no cell contains a zero and that fewer than 20% of cells have expected numbers under 5 [27]. For this reason, in Table 1B, the resident component of the membership was not included in the chi square test, and the usage categories, 1–20%, 20–40%, 40–60%, and 60–80% were combined [27]. Similarly in Table 2, in the analysis of clinicians' experience levels, both gel usage and age group categories were combined. It seems advantageous to leave categories uncombined, to be able to better discriminate between results. In retrospect, for a small group, such as the ASE, the survey could have been designed with fewer response categories to each question. This would have lessened the likelihood of having response numbers under five or zero in cross-tabulations.

Clinicians who use chelating gels are generally satisfied with the physical properties of the gel they use and find them advantageous for creating a glide path in fine or curved canals. While particular manufacturers claim that their gel assists in the reliable use of apex locators [28], few gel users agreed with this statement. Furthermore, there seems to be no scientific evidence to substantiate this claim. However, chelators in general can provide the ions needed for the conductance required for an apex locator to function well [10].

NaOCl is a strong oxidizing agent, and the rapid decrease in its concentration in the presence of EDTA is well documented in the literature [29–31]. In the question on the limitations of chelating agents, only 1% of respondents were concerned about adverse effects, and one respondent specified the depletion of NaOCl in the presence of EDTA. Indeed, in their material safety data sheets, gel manufacturers recommend that their product be kept away from oxidizing agents [12,32], yet some promote the effervescence that occurs [33].

One limitation of this survey was that, as mentioned, some participants misinterpreted the gel usage question. However, the approach taken in the evaluation likely compensated for this. A further limitation is that gel usage patterns could be dissimilar in various countries. A 2014 survey showed that 83% of general dentists in the United States used a chelating gel [16], but this figure was only 55% amongst ASE general dentists. In Russia, gel usage among endodontists and general dentists combined was only 23%, and as mentioned in the introduction, this percentage increased in government-run compared to private clinics [17]. Thus, one factor influencing different gel-usage patterns in various countries

may relate to the form of dental care delivery. Different countries inevitably provide varying mixtures of private versus institutional dental care where the choices of dental materials available are also likely to differ. A further possible reason for disparity in global gel usage is endodontic dental education differences between nations. Irrespective of absolute usage values, it would be informative to investigate if the same differential patterns involving the practitioner type and experience are observed in other countries. Such an analysis may indicate trends in gel usage.

5. Conclusions

Chelating gel usage amongst ASE members depends on the practitioner category and years of endodontic experience. Many who did not use a gel found little benefit of a gel over a liquid chelator, while gel users said that a gel helped them negotiate fine or curved canals. Because older practitioners have higher gel usage, it is possible that the use of chelating gels by ASE members will diminish over time.

Author Contributions: Conceptualization, O.A.P. and P.P.W.; methodology, P.P.W. and E.S.D.; formal analysis, P.P.W. and E.S.D.; resources, O.A.P.; data curation, P.P.W., O.A.P. and E.S.D.; writing—original draft preparation, P.P.W.; writing—review and editing, P.P.W., O.A.P. and E.S.D.; supervision, O.A.P. and P.P.W.; project administration, P.P.W.; funding acquisition, E.S.D., P.P.W. and O.A.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Australian Dental Research Foundation Ltd., grant application number 0008-2021.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the HABS LNR Committee of The University of Queensland (2021/HE001054) on 28 June 2021.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The original data presented in the study are openly available in {UQ eSpace} at URL [https://espace.library.uq.edu.au/view/UQ:31fbf60] (accessed on 24 July 2024).

Acknowledgments: The authors thank Scott Currell for assistance in the formulation of the survey questions and Syeda Farah Zahir from Queensland Cyber Infrastructure Foundation (QCIF) Bioinformatics and Data Science for help with the statistical analysis.

Conflicts of Interest: The authors report that a financial affiliation exists for this paper. O.A.P. has served as a consultant with Dentsply Sirona. The authors P.P.W. and E.S.D. declare no conflicts of interest. The authors declare that this study received funding from Australian Dental Research Foundation Ltd. The funder was not involved in the study design, collection, analysis, interpretation of data, the writing of this article or the decision to submit it for publication.

References

1. Blackman, A.; Bottle, S.; Schmid, S.; Mocerino, M.; Wille, U. *Chemistry*, 5th ed.; John Wiley & Sons: Milton, Australia, 2023; pp. 632–635.
2. Nygaard-Ostby, B. Chelation in root canal therapy. Ethylendiamine tetraacetic acid for cleansing and widening of root canals. *Odontol. Tidskr.* **1957**, *65*, 3–11.
3. Haapasalo, M.; Shen, Y.; Wang, Z.; Gao, Y. Irrigation in endodontics. *Br. Dent. J.* **2014**, *216*, 299–303. [CrossRef] [PubMed]
4. Chandler, N.; Chellappa, D. Lubrication during root canal treatment. *Aust. Endod. J.* **2019**, *45*, 106–110. [CrossRef]
5. Chen, G.; Chang, Y.-C. Effects of liquid-and paste-type EDTA on smear-layer removal during rotary root-canal instrumentation. *J. Dent. Sci.* **2011**, *6*, 41–47. [CrossRef]
6. Peters, O.A.; Boessler, C.; Zehnder, M. Effect of liquid and paste-type lubricants on torque values during simulated rotary root canal instrumentation. *Int. Endod. J.* **2005**, *38*, 223–229. [CrossRef]
7. Qian, W.; Shen, Y.; Haapasalo, M. Quantitative analysis of the effect of irrigant solution sequences on dentin erosion. *J. Endod.* **2011**, *37*, 1437–1441. [CrossRef]
8. Hülsmann, M.; Heckendorff, M.; Schäfers, F. Comparative *in-vitro* evaluation of three chelator pastes. *Int. Endod. J.* **2002**, *35*, 668–679. [CrossRef]
9. Orstavik, D. *Essential Endodontology: Prevention and Treatment of Apical Periodontitis*; John Wiley & Sons: Hoboken, NJ, USA, 2019; p. 294.

10. Peters, O.A.; Arias, A. Shaping, disinfection, and obturation for molars. In *The Guidebook to Molar Endodontics*; Peters, O., Ed.; Springer: Berlin/Heidelberg, Germany, 2017; pp. 133–167.
11. Kim, H.J.; Park, S.J.; Park, S.H.; Hwang, Y.C.; Yu, M.K.; Min, K.S. Efficacy of flowable gel-type EDTA at removing the smear layer and inorganic debris under manual dynamic activation. *J. Endod.* **2013**, *39*, 910–914. [CrossRef] [PubMed]
12. Maillefer Instruments Holding. Glyde File Prep Safety Data Sheet, Version 4.2. Available online: https://gerl-dental.de/media/pdf/81/42/c2/Glyde_File_Prep_20221215_GB.pdf (accessed on 25 May 2024).
13. Tokuda, M.; Kawakami, Y.; Morimoto-Yamashita, Y.; Torii, M. Subcutaneous emphysema caused by sodium hypochlorite plus RC-prep. *Open J. Stomatol.* **2014**, *4*, 527–532. [CrossRef]
14. Dutner, J.; Mines, P.; Anderson, A. Irrigation trends among american association of endodontists members: A web-based survey. *J. Endod.* **2012**, *38*, 37–40. [CrossRef]
15. Virdee, S.S.; Ravaghi, V.; Camilleri, J.; Cooper, P.; Tomson, P. Current trends in endodontic irrigation amongst general dental practitioners and dental schools within the United Kingdom and Ireland: A cross-sectional survey. *Br. Dent. J.* **2020**, 1–7. [CrossRef]
16. Savani, G.M.; Sabbah, W.; Sedgley, C.M.; Whitten, B. Current trends in endodontic treatment by general dental practitioners: Report of a United States national survey. *J. Endod.* **2014**, *40*, 618–624. [CrossRef]
17. Mikheikina, A.; Novozhilova, N.; Polyakova, M.; Sokhova, I.; Mun, A.; Zaytsev, A.; Babina, K.; Makeeva, I. Knowledge, attitude, and practice towards chelating agents in endodontic treatment among dental practitioners. *Dent. J.* **2023**, *11*, 156. [CrossRef] [PubMed]
18. Bartlett, J.; Kotrlik, J.; Higgins, C. Organizational research: Determining appropriate sample size in survey research. *Inf. Technol. Learn. Perform. J.* **2001**, *19*, 43.
19. Beasley, T.M.; Schumacker, R.E. Multiple regression approach to analyzing contingency tables: Post hoc and planned comparison procedures. *J. Exp. Educ.* **1995**, *64*, 79–93. [CrossRef]
20. Bulmer, J.A.; Currell, S.D.; Peters, C.I.; Peters, O.A. Endodontic knowledge, attitudes and referral patterns in Australian general dentists. *Aust. Dent. J.* **2022**, *67* (Suppl. S1), S24–S30. [CrossRef]
21. Cheung, M.C.; Peters, O.A.; Parashos, P. Global survey of endodontic practice and adoption of newer technologies. *Int. Endod. J.* **2023**, *56*, 1517–1533. [CrossRef]
22. Peters, O.A.; Rossi-Fedele, G.; George, R.; Kumar, K.; Timmerman, A.; Wright, P.P. Guidelines for non-surgical root canal treatment. *Aust. Endod. J.* **2024**. *online ahead of print*. [CrossRef]
23. Duncan, H.F.; Kirkevang, L.L.; Peters, O.A.; El-Karim, I.; Krastl, G.; Del Fabbro, M.; Chong, B.S.; Galler, K.M.; Segura-Egea, J.J.; Kebschull, M. Treatment of pulpal and apical disease: The European Society of Endodontology (ESE) S3-level clinical practice guideline. *Int. Endod. J.* **2023**, *56* (Suppl. S3), 238–295. [CrossRef]
24. American Association of Endodontists. Treatment Standards: Executive Summary. Available online: https://www.aae.org/specialty/wp-content/uploads/sites/2/2019/11/EndoCompetency_2019.pdf (accessed on 10 July 2024).
25. Keyes, K.M.; Utz, R.L.; Robinson, W.; Li, G. What is a cohort effect? Comparison of three statistical methods for modeling cohort effects in obesity prevalence in the United States, 1971–2006. *Soc. Sci. Med.* **2010**, *70*, 1100–1108. [CrossRef]
26. Ju, X.; Spencer, A.J.; Brennan, D.S. Dentist age, period and cohort effects on provision of dental services in Australia: 1983-84 to 2009-10. *Community Dent. Oral Epidemiol.* **2017**, *45*, 242–250. [CrossRef] [PubMed]
27. Kirkwood, B.; Sterne, J. *Essential Medical Statistics*, 2nd ed.; Blackwell Science: Carlton, Australia, 2003; p. 171.
28. Premier Dental. RC-Prep®. Available online: https://www.premierdentalco.com/product/endo/chemo-mechanical-preparation/rc-prep/ (accessed on 18 June 2024).
29. Clarkson, R.M.; Podlich, H.M.; Moule, A.J. Influence of ethylenediaminetetraacetic acid on the active chlorine content of sodium hypochlorite solutions when mixed in various proportions. *J. Endod.* **2011**, *37*, 538–543. [CrossRef]
30. Wright, P.P.; Cooper, C.; Kahler, B.; Walsh, L.J. From an assessment of multiple chelators, clodronate has potential for use in continuous chelation. *Int. Endod. J.* **2020**, *53*, 122–134. [CrossRef] [PubMed]
31. Zehnder, M.; Schmidlin, P.; Sener, B.; Waltimo, T. Chelation in root canal therapy reconsidered. *J. Endod.* **2005**, *31*, 817–820. [CrossRef] [PubMed]
32. Ultradent Products. Safety Data Sheet File-Eze. Available online: https://www.ultradent.com/Resources/GetSds?key=21-001-09.82735475-en-gb (accessed on 25 May 2024).
33. Utradent Products. File-Eze™EDTA Chelating & Filing Lubricant Instructions for Use. Available online: https://assets.ctfassets.net/wfptrcrbtkd0/53ba3c2e-8e18-4e91-a9ab-c0d7d03671bf/0bbc938116f42cd0532c93bb5b1a7953/File-Eze-EDTA-File-Lubricant-IFU-10187-UAR10.pdf (accessed on 18 June 2024).