ABSTRACT

Introduction: Inconsistencies in the definitions of endodontic outcome terminology jeopardize evaluations of proposed interventions and patient care quality. This scoping review aimed to provide groundwork to develop a set of basic outcomes in endodontics.

Methods: We performed a comprehensive literature search for randomized controlled trials, cohort studies, case-control studies, and case series (>10 patients) published after 1980 with patients ≥10 years of age with any preoperative pulpal and periapical diagnosis in permanent teeth requiring nonsurgical root canal treatment, retreatment, or apexification. Abstracted data on outcome assessment methods, assessors, and domains were reported after univariate and bivariate analyses.

Results: Treatment outcomes were evaluated radiographically (88%) or clinically (73%). Although 2-dimensional radiography exceeded 3-dimensional radiography, the use of the latter has increased since 2010, mostly for nonsurgical retreatments. Of 19 identified outcomes, 5 were most frequent: success (168 studies, 40%), radiographic healing (128 studies, 30%), survival (of an asymptomatic tooth [48 studies, 12%] or of a procedure code in administrative databases [31 studies, 7%]), pain assessment (14 studies, 3%), and quality of life (11 studies, 3%). Clinician-centered outcomes have been most frequently studied since the 1980s (71%), in academic settings (76%), and using a prospective design (45%). Patient-centered outcomes were reported in 19% of studies before 2010 and 30% since 2010. They were more common among retrospective studies (49%).

Conclusions: Patient-centered outcome measures are lacking in endodontic studies. The state of available research can provide a baseline for the development of a core outcome set in endodontics, which should represent the important patient-centered outcomes in conjunction with well-validated clinician-centered outcomes. (J Endod 2022;48:29–39.)

KEY WORDS
Dental pulp diseases; endodontic study outcomes; scoping review

An increasing number of studies have assessed the outcomes of nonsurgical root canal treatment (NS-RCT), nonsurgical retreatment (NS-ReTx), and apexification in the last 4 decades. Over time, definitions of outcome measures and their focus have changed. Whether any of those reported outcomes are crucial to the clinician or the patient remains questionable.1

Outcomes in health are defined as “the change in a patient’s current and future health status that can be attributed to preceding healthcare”.2 Therefore, identification of the appropriate outcome and its
measurement tool(s) is a fundamental aspect of both clinical research and practice. Outcomes have different interpretations for patients, clinicians, and researchers, and variations exist in the emphasis of these components. Outcomes evaluate the proposed intervention and thus the quality of patient care. Hence, well-established outcomes in evidence-based dental care are crucial for evaluating, making, and defending clinical decisions.

It is evident that many factors have shaped the development of outcome measures in endodontics. General characteristics of outcome studies on NS-RCT, NS-ReTx, and apexiton were presented in part 1 of this scoping review series. The aim of the second part of this scoping review was to provide a baseline work for the development of a standardized number of fundamental outcomes in endodontics supported by literature mapping on outcomes reported for NS-RCT, NS-ReTx, and apexiton while identifying key outcome-related concepts and gaps in the research.

### METHODS

The methodology of this scoping review including the search strategies, study selection, data charting, and quality assurance were presented in detail in part 1. Using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews checklist and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines for protocols, we completed a scoping review of 354 randomized controlled trials, cohort studies, cross-sectional studies, case-control studies, and case series with ≥10 patients. These studies were published after 1980 in any language and addressed treatment outcomes of NS-RCT, NS-ReTx, and apexiton in patients ≥10 years old. We collected the following information:

1. Outcome assessment methods: categorized as clinical, 2-dimensional (2D) (eg, periapical radiographs), and 3-dimensional (3D) (eg, cone-beam computed tomographic radiographic imaging) and then merged to identify the summary version of the type of assessment for analysis
2. Outcome assessors: any dental specialists were recorded as “specialists”; graduate students in any dental specialty were recorded as “postgraduate students”
3. Outcome measures: they were defined as follows:\(^1,5\):
   a. Success: assessment of pain and clinical evidence of inflammation or swelling and periapical healing/periodontal ligament space as assessed by clinical examination and conventional radiographic measures, respectively
   b. Survival: either as survival of asymptomatic presence of the tooth in the mouth (assessment based on the resolution of clinical signs and symptoms without considering radiographic parameters) or survival of the procedure code in administrative databases (assessment based on following the tooth in a database [hence, no clinical or radiographic assessments were performed] until untoward event or reintervention [eg, endodontic retreatment, apical surgery, or tooth extraction] occurred)
   c. Radiographic healing: cases in which no clinical examination is available and only radiographic assessments were performed
4. Outcome domains: we adapted Fletcher and Fletcher’s 5D’s model\(^6\) in defining our working template “The 6Ds model: Outcomes of Endodontic Disease” (Table 1), which provides the foundational aspects for categorizing endodontic outcomes into patient-centered domains. Using this model, treatment outcome measures were categorized as follows:
   a. Patient-centered outcomes: “reported by patients as important to them in the way they experience a disease or treatment for that disease,”\(^7\) including quality of life, cost, and symptoms of improvement
   b. Clinician-centered outcomes: those obtained by a trained health care professional through an interpretation of the clinical signs and physical manifestations of the patient’s condition.

### TABLE 1 - The 6 Ds Model for Outcomes of Endodontic Treatment: The 6 Domains Representing the Most Important Health Outcomes as Related to Patients\(^6\)

<table>
<thead>
<tr>
<th>Outcome of disease</th>
<th>Adaptation to endodontics</th>
<th>Classification of measures</th>
<th>Emphasis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death</td>
<td>A bad outcome if untimely</td>
<td>Fatality due to endodontic cause, tooth extraction</td>
<td>Survival</td>
</tr>
<tr>
<td>Disease</td>
<td>A set of symptoms, physical signs, and laboratory abnormalities</td>
<td>Signs and symptoms related to pulp or periapical pathosis</td>
<td>Success, healed/healing/diseased state</td>
</tr>
<tr>
<td>Discomfort</td>
<td>Symptoms such as pain, nausea, dyspnea, itching, and tinnitus</td>
<td>Evoked or spontaneous symptoms such as thermal sensitivity, pain on chewing, or swelling</td>
<td>Pain assessment</td>
</tr>
<tr>
<td>Disability</td>
<td>Impaired ability to go about usual activities at home, work, or recreation</td>
<td>Impaired ability to conduct activities of daily living due to problems with teeth or mouth</td>
<td>Oral health-related quality of life, chewing ability</td>
</tr>
<tr>
<td>Dissatisfaction</td>
<td>Emotional reaction to disease and its care, such as sadness or anger</td>
<td>Emotional response to the disease or any of its related care</td>
<td>Patient satisfaction, esthetic evaluation</td>
</tr>
<tr>
<td>Destitution</td>
<td>Financial cost of illness to individual patients or society</td>
<td>Direct and indirect cost of illness</td>
<td>Treatment costs, number of visits needed, treatment time</td>
</tr>
</tbody>
</table>

*No included studies reported measures related to fatality due to an endodontic cause.
1 Per the domains of oral health-related quality of life\(^10\) can be functional limitation (trouble pronouncing words, worsened sense of taste), physical pain (painful aching, uncomfortable to eat any foods), psychological discomfort (self-conscious, felt tense), physical disability (unsatisfactory diet, had to interrupt meals), psychological disability (found it difficult to relax, difficult to fall asleep, awakened, embarrassed), social disability (inhabitable with other people, difficulty doing your usual jobs), or handicap (felt that life in general was less satisfying, totally unable to function).
and not on symptoms that are known only to the patient such as pain intensity, including surrogate outcomes that may or may not lead to improvements in patient outcomes.

c. Research-centered outcomes: not directly related to the clinical manifestations of the disease or condition but focused on addressing a specific question through science and moving the field forward to substantive advances in care.

A hierarchy of outcome domains was created from most patient centered to least patient centered as follows: patient centered, clinician centered, and research centered. Each study was assigned the same domain categorization as the outcome. If more than 1 outcome was reported, the highest domain categorization of all outcomes reported was assigned as the study’s domain categorization.

The target analytics were reported through descriptive statistics by univariate analysis reported in terms of frequency metrics. In addition, simple bivariate analyses were performed to show relationships between treatment outcome measures and study characteristics. Data cleaning and analysis were performed using SPSS Version 24 (IBM Corp, Armonk, NY).

RESULTS

The overall results of the scoping review were described in part 1 of this series and the full report (Supplemental Material 1 is available online at www.jendodon.com). This section provides details related to the results of outcome-related variables that were abstracted from the included 345 outcome studies. The detailed abstracted data are presented in Supplemental Material 2 (available online at www.jendodon.com).

Outcome Measurement Tools

In measuring the outcome, clinical and radiographic evaluations were performed in 73% (n = 259) and 88% (n = 311) of the studies, respectively (Table 2). For the latter, 3D evaluation was used for only a small number of studies, either in combination with 2D evaluation (20 studies, 6%) or as the only mode of radiographic evaluation (6 studies, 2%). These 26 studies were published only in the last decade of our investigation (2010–2020) and focused mostly on NS-ReTx (Fig. 1). Approximately 38% (119/311) of the studies that incorporated radiographic assessment of periapical structures used the periapical index as their assessment tool. In 117 of the studies, the periapical index (PAI) was used, whereas in 7 the cone-beam computed tomographic (CBCT) PAI was used (Table 2).

The information on outcome assessor was reported in less than half of the included studies (n = 167, 47%). In the majority of these studies (n = 128), outcome assessment was performed by specialists followed by general practitioners (n = 17) and both general practitioners and specialists (n = 2). In the 20 remaining studies, the outcome assessors were underground or postgraduate students under the supervision of their supervisors (Table 2).

<table>
<thead>
<tr>
<th>Methods of outcome assessment (n = 881)</th>
<th>Frequency (n)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical examination</td>
<td>259</td>
<td>73</td>
</tr>
<tr>
<td>Radiologic examinations (all)</td>
<td>311</td>
<td>88</td>
</tr>
<tr>
<td>Only 2D</td>
<td>285</td>
<td>81</td>
</tr>
<tr>
<td>2D and 3D</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>Only 3D</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Categories of outcome assessors (n = 354)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specialist</td>
<td>128</td>
<td>36</td>
</tr>
<tr>
<td>General practitioner/specialist</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>General practitioner</td>
<td>17</td>
<td>5</td>
</tr>
<tr>
<td>Postgraduate, with or without general practitioner or specialist</td>
<td>18</td>
<td>5</td>
</tr>
<tr>
<td>Undergraduate, with or without general practitioner or specialist</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Missing</td>
<td>187</td>
<td>53</td>
</tr>
<tr>
<td>Studies that reported PAI as an outcome (n = 119)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAI</td>
<td>112</td>
<td>32</td>
</tr>
<tr>
<td>PAI and CBCT PAI</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>CBCT PAI</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Masking of outcome assessors (n = 156)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>156</td>
<td>44</td>
</tr>
</tbody>
</table>

2D, 2-dimensional; 3D, 3-dimensional; CBCT, cone-beam computed tomography; PAI, periapical index.

TABLE 2 - The Number and Percentage of the Included Endodontic Outcome Studies by Type of Outcome Assessment and Outcome Assessor Categories

Outcomes Measures

Because some included studies reported more than 1 outcome measure (average of 1.2 outcomes per study), a total of 422 outcomes were investigated in the 354 studies included in this review (Table 3). Overall, 19 distinct outcome measures were reported in the included studies. A total of 296 studies included 300 clinician-centered outcome measures (success in 168 studies, radiographic healing in 128 studies, time to apical barrier formation in 2 studies, apical barrier formation in 1 study, and clinical impression of healing in 1 study). Research-centered outcomes were observed in 8 studies and included microbial evaluation (4 studies), histologic evaluation (2 studies), densitometric analysis of apical barrier (1 study), and root thickness (1 study). Finally, a total of 102 studies included 114 patient-centered outcome measures, namely survival of an asymptomatic tooth (48 studies), survival of a procedure code in administrative databases until an untoward event or reintervention occurred (31 studies), pain assessment (14 studies), patients’ quality of life (11 studies), patients’ satisfaction (4 studies), and treatment time (2 studies). Other criteria such as chewing ability, esthetic evaluation, number of visits needed, and treatment cost were each observed in 1 study. Given the hierarchy of outcome domain, 252 (71%) and 102 studies (29%) were identified as clinician- and patient-centered studies, respectively.

Synthesized Results of the Outcome Measures

Between 1980 and 2020, we noted a relative decrease in reporting of radiographic healing and success as outcomes of endodontic treatment and a small but steady relative increase in reporting of survival, pain assessment, and quality of life (Fig. 2A). This trend is reflected in the outcome domains by an increase in the number of patient-centered studies and a decrease in clinician-centered studies in the 1990s (Fig. 2B). In terms of study design, cohort studies most frequently were patient centered (35%) compared with randomized controlled trials and case series (18% and 10%, respectively) (Fig. 3). Among the included patient-centered studies, the most prevalent study design was cohort (84%) (Fig. 4A), whereas 63% of studies had a retrospective design (49% retrospective and 14% ambispective-retrospective with follow-up) (Fig. 4B).

Among the published studies included in this review, clinician-centered studies represented 33%–34% of each of the sample size categories (<100, 101–500, and 501–1000). As the sample size increased, the proportion of studies categorized as patient-
centered increased; studies with sample sizes >1000 had the highest proportion of studies classified as patient centered (65%) and were mostly retrospective. Published studies classified as clinician centered were more likely to have sample sizes <500 (85%) compared with patient-centered studies (61%). Sixty-five percent of studies with sample sizes >1000 were patient centered compared with 35% categorized as clinician centered (Fig. 3).

A greater proportion of studies from private sector settings were categorized as patient centered (42%) compared with academic settings (24%). In contrast, studies from academic settings (35%) were assigned a clinician-centered classification more frequently (76%) than studies in a private sector setting (58%) (Fig. 3).

No major differences in the distribution of the outcome domain categories were noted when different treatment strategies were analyzed, although only 14% of apexification studies were categorized as patient centered compared with 32% and 25% in NS-RCT and NS-ReTx studies, respectively (Fig. 3).

Synthesized data on outcome measures and domains are presented in Figures 4 and 5.

**DISCUSSION**

To our knowledge, this is the first scoping review on the assessment of published outcomes in nonsurgical endodontic treatment, retreatment, and apexification conducted for identifying key concepts and gaps in endodontic research. In terms of limitations related to reporting the outcomes, despite the evident progress in endodontics and its research, we have noted inconsistencies and challenges in data standardization and significant heterogeneity in the definitions and interpretations of the reported outcomes as evidenced by both the number of outcome measures and change of definitions over the years. These include underreporting of crucial information, reporting of surrogate outcomes that do not benefit the patients or the clinicians, and a lack of transparency in the reported outcomes. Thus, there is a need for a reproducible and standardized core outcome set (COS), which includes a predetermined set of terms for standardized assessment of outcomes available as a uniform framework for the investigators, clinicians, and patients.

We identified 19 endodontic treatment outcome measures, of which 5 were frequently used, namely radiographic healing, success, survival, pain assessment, and quality of life.

Almost all of our included studies used radiographic tools in the assessment of their outcomes (mostly success and radiographic healing). As such, one may expect the use of unbiased, masked, and previously calibrated outcome assessors as well as enhancement in radiographic technology to ensure maximal outcome strength and validity. However, missing information about the outcome assessor and treatment provider was a significant issue because only half of the included studies reported information about the type of outcome assessors. Even if masking of clinicians and patients is not practical, as is often the case in endodontics, it remains critical to mask outcome assessors with appropriate skills and knowledge to assure the reproducibility of the reported results. Unblinded outcome assessors may unwittingly apply their own bias into the intervention, particularly when the outcome measure involves subjectivity.

Furthermore, the PAI has been used in a broad range of study designs and has been further improved by the induction of precalibration. However, we found that only 40% of the studies (with radiographic assessment) used this well-validated tool, which is potentially explained by the inherent limitations of 2D radiographs, especially when evaluating maxillary molars (due to the overlap by dense radiopaque zygomatic processes) or small mandibular lesions. Furthermore, the presence of a thick mandibular plate can

**FIGURE 1** – The proportion of studies categorized by radiographic outcome assessment tool per decade and treatment type.

**FIGURE 2** – Trends in the use of outcome measures over 40 years. (A) Six most common outcome measures; and (B) patient and clinical centered studies.
create difficulties in the diagnosis of small mandibular lesions. The calibration of observers may also pose a challenge for some investigators, further contributing to PAI disuse.

CBCT imaging eliminates the superimposition of anatomic structures, thus overcoming some of the limitations of 2D radiographs. CBCT imaging was first developed in the 1980s followed by the introduction of units dedicated to the orofacial complex in the 1990s. In the 2000s, it became popular in oral radiology, oral surgery, implantology, orthodontics, and endodontics,15,16 which was confirmed by our review findings. However, there are still concerns regarding the effective doses of CBCT units, which require clinicians to be prudent with their CBCT prescribing habits to maximize diagnostic value while limiting the risk to the patient15,16 and the cost to the patient. The American Association of Endodontists and the American Academy of Oral and Maxillofacial Radiology17 recommend against CBCT use in diagnosis or screening without clinical signs or symptoms and attest that other conventional lower-dose radiographic modalities are sufficient. Less than 10% of endodontic outcome studies published within the last decade used CBCT imaging in measuring their radiographic healing outcome. With an increased popularity of CBCT imaging in clinical practice, future retrospective studies from practice-based research networks can use this preexisting information to assess prognostic factors for the outcome of endodontics. Radiographic healing has been used throughout the years in assessing the presence, progression, regression, and persistence of apical periodontitis after endodontic treatment.11,16 This clinician-centered outcome is directly related to a patient’s perspective of disease progression and resolution. It is no surprise that almost 90% of our included studies used radiographic tools in the assessment of their outcomes. Moreover, radiographic healing is a major component of 1 of the first standardized outcome criteria in endodontics—Strindberg’s 1956 criteria of success.19 Although these criteria consider comprehensive clinical and anamnestic patient symptoms, it emphasizes the radiographic component and, therefore, is heavily biased toward the clinician when assessing the “failed” cases. For example, a radiographic lesion that only partially decreased in size was considered a failure, even for asymptomatic cases with almost complete resolution of the radiographic lesion.14 Nonetheless, these 2 clinician-centered outcome measures (or their adaptations in Supplemental Material 3 [available online at www.jendodon.com]) have been used in 85% of our included studies, particularly during the first 2 decades of this review (1980–2000) for which they were used exclusively.

In the early 2000s, Friedman argued that the strict criteria of “success” as defined previously caused confusion for clinicians and patients,30 so he redefined the classifications as “healed,” “healing,” and “diseased.” He also identified an independent outcome criterion (ie, “functional retention”) wherein the tooth is retained in asymptomatic function irrespective of the presence of newly emerged or persisting radiolucency.30 Concurrently, survival (ie, the asymptomatic presence of the tooth in the mouth) was also introduced into the literature. This definition ignores the clinical condition at recall and is a slightly more lenient definition compared with functional retention.27 The emergence of these criteria developed partially in response to a trend in favoring the alternative treatment option (ie, tooth extraction and replacement with an implant-supported prosthesis).25–27 The stringent criteria of implant success, defined as radiographic and clinical normalcy,28,29 are not routinely applied in much of the implant outcome literature.20–32 In fact, implant outcome studies have been more inclined to use a less stringent criteria of survival—physical presence in the mouth regardless of pain or infection.25,33 Consequently, survival and functional retention provided a more fair and direct comparison between outcomes of endodontic treatment and an implant-supported prosthesis. This signified the shift in the focus of endodontic outcomes from clinician-centered to patient-centered care, highlighting patient autonomy in

### TABLE 3 - The Number and Percentage of Included Studies by Treatment Type and Outcome Measure in Each Outcome Domain

<table>
<thead>
<tr>
<th>Domain</th>
<th>Outcome</th>
<th>Apexification, n (%)</th>
<th>NS-RCT, n (%)</th>
<th>NS-Re-Tx, n (%)</th>
<th>NS RCT and Re-Tx, n (%)</th>
<th>NS unidentified, n (%)</th>
<th>Total, N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient centered</td>
<td>Chewing ability</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (100)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (0.2)</td>
</tr>
<tr>
<td></td>
<td>Esthetic evaluation</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (100)</td>
<td>0 (0)</td>
<td>1 (0.2)</td>
</tr>
<tr>
<td></td>
<td>OHRQOL</td>
<td>0 (0)</td>
<td>6 (55)</td>
<td>1 (19)</td>
<td>4 (36)</td>
<td>0 (0)</td>
<td>11 (2.6)</td>
</tr>
<tr>
<td></td>
<td>Number of visits needed</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (100)</td>
<td>0 (0)</td>
<td>1 (0.2)</td>
</tr>
<tr>
<td></td>
<td>Pain assessment</td>
<td>0 (0)</td>
<td>11 (79)</td>
<td>1 (7)</td>
<td>2 (14)</td>
<td>0 (0)</td>
<td>14 (3)</td>
</tr>
<tr>
<td></td>
<td>Patients’ satisfaction</td>
<td>0 (0)</td>
<td>4 (100)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>4 (100)</td>
<td>4 (1)</td>
</tr>
<tr>
<td></td>
<td>Survival (asymptomatic tooth)</td>
<td>4 (8)</td>
<td>27 (56)</td>
<td>4 (8)</td>
<td>11 (23)</td>
<td>2 (4)</td>
<td>48 (11)</td>
</tr>
<tr>
<td></td>
<td>Survival (procedure code in administrative database)</td>
<td>0 (0)</td>
<td>24 (77)</td>
<td>1 (3)</td>
<td>4 (13)</td>
<td>2 (6.5)</td>
<td>31 (7)</td>
</tr>
<tr>
<td></td>
<td>Treatment time</td>
<td>0 (0)</td>
<td>2 (100)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>2 (0.5)</td>
</tr>
<tr>
<td></td>
<td>Treatment cost</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (100)</td>
<td>0 (0)</td>
<td>1 (0.2)</td>
</tr>
<tr>
<td>Clinician centered</td>
<td>Success</td>
<td>21 (12.5)</td>
<td>86 (51)</td>
<td>14 (8)</td>
<td>46 (27)</td>
<td>1 (0.6)</td>
<td>168 (40)</td>
</tr>
<tr>
<td></td>
<td>Radiographic healing</td>
<td>5 (4)</td>
<td>83 (65)</td>
<td>12 (9)</td>
<td>28 (22)</td>
<td>0 (0)</td>
<td>128 (30)</td>
</tr>
<tr>
<td></td>
<td>Apical barrier formation time</td>
<td>2 (100)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>2 (0.5)</td>
</tr>
<tr>
<td></td>
<td>Apical barrier formation</td>
<td>1 (100)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (0.2)</td>
</tr>
<tr>
<td></td>
<td>Clinic impression of healing</td>
<td>0 (0)</td>
<td>1 (100)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (0.2)</td>
</tr>
<tr>
<td>Research centered</td>
<td>Microbial evaluation</td>
<td>0 (0)</td>
<td>4 (100)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>4 (1)</td>
</tr>
<tr>
<td></td>
<td>Histologic evaluation</td>
<td>0 (0)</td>
<td>2 (100)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>2 (0.5)</td>
</tr>
<tr>
<td></td>
<td>Densitometric analysis of apical barrier</td>
<td>1 (100)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (0.2)</td>
</tr>
<tr>
<td></td>
<td>Root thickness</td>
<td>1 (100)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (0.2)</td>
</tr>
</tbody>
</table>

NS, nonsurgical; NS-RCT, nonsurgical root canal treatment; NS-Re-Tx, nonsurgical retreatment; OHRQOL, oral health–related quality of health.
setting less demanding goals for treatment.\textsuperscript{4,20} 

Currently, the representation of these outcome measures is still low (43 studies [12%]).

In recent years, there has been a rise in large-scale retrospective cohort studies on the survival of procedure codes in administrative databases (eg, advanced registration or large insurance databases). Such studies are predominantly conducted in developed regions due to the greater availability and accessibility to preexisting databases advanced registration or large insurance databases.\textsuperscript{34} In such cases, the procedure code is followed until any untoward event or reintervention occurs (eg, progression from NS-RCT to either NS-ReTx, apical surgery, or tooth extraction). Our review identified a low representation of this outcome (31 studies, 8%); however, given their large sample size, they can effectively speak to the outcome of endodontics in the real world and hence are more generalizable.\textsuperscript{35,36} It is worth noting that accruing data may be of limited value at the patient level but may be of use from a public health perspective.

In this review, we were able to incorporate patient-centered concepts toward the outcome analysis. We used an adapted version of Fletcher and Fletcher’s 5D’s model to further standardize the categorization of patient-centered outcome domains.\textsuperscript{35} This is a well-established model in health care that is used to define the most important health outcomes for patients who have generally been ignored by health care providers.\textsuperscript{37} As such, it was chosen as a strong framework to categorize endodontic patient-centered outcomes. We identified that less than 3% of the included studies measured patient concerns such as (oral) health-related quality of life, patient satisfaction, chewing ability, and

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**FIGURE 3**—Synthesized data cross-tabulation of outcome domains by study variables.
treatment costs. These patient-centered outcomes are valuable in improving communication between patients and providers and the clinicians’ ability to meet the patients’ needs and expectations. Arguably, these measures can enhance the clinician-centered outcome and should be considered in future outcome research.

Over the last 4 decades, clinician-centered outcome studies have been the dominant categorization (71%). Our results are in accordance with a recent scoping review that reported a disproportionate emphasis on clinician-centered outcomes among all dental specialties. Nonetheless, we observed a rise in

FIGURE 4 – Synthesized data cross-tabulation of the 6 most prevalent outcome measures by study design variables. (A) Study design; and (B) study temporal design.
the number of patient-centered studies from only 1 study (4%) in the 1990s to 31% in the 2000s to 36% in the most recent decade of our review (2010s). These events parallel the overall health care goal toward a more patient-centered emphasis introduced in the 1980s and closely follow the historical development of patient-centered models. Furthermore, only 13% of patient-centered studies were randomized controlled trials compared with 22% in clinician-centered studies. We hope to continue to observe this trend in increasing the number of patient-centered studies, along with the publication of study designs at a higher level of evidence, such as prospective and randomized controlled trials.

**Implication for Future Outcome Research: Need for COS in Endodontics**

Endodontic outcomes encompass both clinical measures, which are beneficial in reporting the efficacy of treatment, as well as patient-level measures, which report on the negative impacts of the disease/condition.\(^{40,41}\) It is evident that over the years both the definitions and focus of outcome measures have changed. Despite the increasing importance of patient-centered care in the literature, patients, clinicians, and researchers all contribute independent perspectives as to which outcome measures are most critical.\(^{21}\) Since the increased emergence of patient-centered studies in health care, many have disputed the importance of clinician-centered outcomes. However, this discussion is fundamentally unproductive because both aspects are needed.\(^{42}\) Investigators of future studies are encouraged to include both patient- and clinician-centered outcome assessments. Furthermore, significant heterogeneity was evident in the reporting of outcomes in the included studies. This causes challenges for evidence-based clinical practice and can hinder the uptake of new evidence by clinicians and researchers.\(^{40,41,45,46}\) In part, this can be attributed to the wide variety and variability in outcome measures. Such a lack of standardization can result in marked outcome reporting bias\(^{45}\) and prevent conducting valuable high-quality meta-analyses, resulting in wasted opportunities to enhance patient care.\(^{40,41,45,46}\) Hence, it is evident that there is a need for the development of a reproducible standardized number of fundamental outcomes known as a COS.

A COS includes a predetermined number of terms for standardized assessment available in a uniform framework for investigators, clinicians, and patients.\(^{40,41}\) The included outcome measures have high validity, reliability, and responsiveness and are easy to use. Adhering to this set does not necessitate researchers and clinicians to exclusively use these outcomes; rather, they will act as the fundamental framework of minimum and core measured outcomes, which should always be collected and reported.\(^{40,41}\) The development of a COS and its benefits have been reported in the literature in areas outside of dentistry, as seen in the implementation of the Core Outcome Sets in Women in Newborn Health initiative\(^{46}\) and Outcome Measures in Rheumatology Trials\(^{47}\) for the management of rheumatoid arthritis, which saw improvements in the evidence synthesis and homogeneity between studies.\(^{43,45}\) When applied to endodontics, the COS will help address the evident heterogeneity between studies and ensure that data between studies can be compared and synthesized, therefore facilitating the establishment of meta-analysis of endodontic outcomes studies, which, in turn, improves the quality of evidence.

This review can aid in determining the minimum set of core outcomes that should be measured and reported when investigating endodontic treatments. This will allow future researchers to match the intervention with the intended COS, and routine measurement will improve the effectiveness and efficiency of comparative research on different interventions. Although we acknowledge the value of clinician-centered outcomes, including radiographic healing, PAI, and clinical normalcy, we cannot overlook the importance of incorporating patient-centered outcomes, such as (oral) health-related quality of life, patient satisfaction, pain (particularly, persistent pain), survival, chewing ability, and treatment costs into the standardized COS. Regarding persistent pain, there is evident consensus of its mild to significant effect on patients’ quality of life despite disagreement across studies in considering when pain is identified to be persistent (ranging from 3 months–5 years) and the subsequent discrepancy in reported incidence rates (1%–19%).\(^{49,50}\) Studies report long-term implications including being kept from usual activities like eating and toothbrushing, interference with ability to work, and psychological discomfort and disability.\(^{50,53,55}\) Risk factors include the presence and duration of preoperative pain from the treated area, a positive history of previous pain and/or painful treatment in the orofacial region, and female sex. Thus, it is
worth considering the additional patient-centered outcome of persistent pain, independently or as a subcategory of pain.49

Arguably, a future COS should not only be based on strong evidence in order to provide more accurate predictions but should also focus on the following most important health outcomes according to patients’ perspectives: death, disease, discomfort, disability, and dissatisfaction. These domains have been discussed in the literature since the 1960s59 and were further adapted and expanded by Fletcher and Fletcher6 to include an additional domain—destitution. Our adapted version of Fletcher and Fletcher’s model “The 6 Ds Model: Outcomes of Endodontic Disease” (Table 1) enabled us to identify the outcomes that should be categorized as patient centered. We propose these findings in the context of clinical epidemiology, the fundamental core science when treating patients. As such, we believe this adapted model can help guide further discussion in the identification of the important patient-centered outcomes that can complement well-validated clinician-centered outcomes.

CONCLUSIONS

In this scoping review, we highlighted the state of available research and summarized the reported outcomes for nonsurgical endodontic treatments and apexification in order to provide a baseline work for the development of a COS in endodontics. Additionally, we proposed an adaptation of the established models that can facilitate the identification of the COS to represent the important patient-centered health outcomes in conjunction with well-validated clinician-centered outcomes. We hope our generated guidelines help develop a COS to promote standardization in data acquisition and facilitate dissemination of evidence while allowing easier replication and literature synthesis in the future.

REFERENCES


