Periapical status and quality of root fillings and coronal restorations in an adult Spanish population

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Abstract

Segura-Egea JJ, Jiménez-Pinzón A, Poyato-Ferrera M, Velasco-Ortega E, Ríos-Santos JV. Periapical status and quality of root fillings and coronal restorations in an adult Spanish population. *International Endodontic Journal*, **37**, 525–530, 2004.

Aim To investigate the quality of root fillings and coronal restorations and their association with periapical status in an adult Spanish population.

Methodology A total of 180 subjects, aged 37.1 ± 15.7 years, who presented as new patients at the Faculty of Dentistry, Seville, Spain, were examined. All participants underwent a full-mouth radiographic survey incorporating 14 periapical radiographs. The periapical region of all root filled teeth, excluding third molars, were examined. The technical quality of root fillings was evaluated in terms of length in relation to the root apex and lateral adaptation to the canal wall. Radiographic signs of overhang or open margins associated with coronal restorations were also evaluated. Periapical status was assessed using the Periapical Index score. Statistical analyses were conducted using the Cohen's κ test and logistic regression.

Results The total number of root filled teeth was 93, and 60 (64.5%) had apical periodontitis (AP). Presence of AP in root filled teeth was associated with inadequate adaptation of the filling (OR = 2.29; $P = 0.06$), inadequate length of the root filling (OR = 2.44; $P = 0.048$), and with poor radiographic quality of the coronal restoration (OR = 2.38; $P = 0.054$). Only 34.4% of the root fillings were adequate from a technical perspective. When both root fillings and coronal restorations were adequate the incidence of AP decreased to 31.3% (OR = 5.50; $P < 0.01$).

Conclusions The incidence of AP in root filled teeth was high. Many root fillings were technically unsatisfactory. Adequate root fillings and coronal restorations were associated with a lower incidence of AP; an adequate root filling had a more substantial impact on the outcome of treatment than the quality of the coronal restoration.

Keywords: apical periodontitis, coronal restoration, endodontics, periapical status, root fillings.

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Introduction

Follow-up clinical studies have shown that root canal treatment applying modern principles of practice can yield favourable outcomes, with healing rates well above 90% (Sjögren *et al.* 1990, Ørstavik 1996, Friedman 1998). However, most of the investigations on the quality and prognosis of root canal treatment have been based on clinical studies made in controlled environments at dental schools or in specialist clinics (Strindberg 1956, Ørstavik & Hörsted-Binslev 1993, Çaliskan & Sen 1996, Iqbal *et al.* 2003). The high rates of success reported in these studies were obtained with well-trained practitioners under strict operating conditions that may not reflect the situation found within the average dental clinic (Boucher *et al.* 2002). Such studies demonstrate the potential outcome of root canal treatment rather than its realistic outcome in general practice (Eriksen *et al.* 2002).

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Recent endodontic epidemiological studies carried out in different population groups report a high prevalence of apical periodontitis (AP) in connection with root filled teeth ranging from 16 to 65% (Weiger *et al.* 1997, Eriksen 1998, Kirkevang *et al.* 2001, Dugas *et al.* 2003, Jiménez-Pinzón *et al.* 2004), as well as a frequent finding of root fillings of inadequate quality (Ödesjö *et al.* 1990, Marques *et al.* 1998, Sidaravicius *et al.* 1999, Kirkevang *et al.* 2000, Lupi-Pegurier *et al.* 2002). These epidemiological studies point to an association between the quality of root canal treatment and periapical bone status, and conclude that an improvement in the quality of root canal treatment in general dental practice was required in order to promote periapical health (Kirkevang *et al.* 2000). In addition, it has been suggested that the quality of the coronal restoration may be of greater importance for the periapical status than the quality of the endodontic treatment (Ray & Trope 1995, Sidaravicius *et al.* 1999, Iqbal *et al.* 2003).

The aim of the present study was to relate the quality of root canal treatment and coronal restorations to the periapical status of root filled teeth in an adult Spanish population based on radiographic examination.

Materials and methods

Patient selection

The sample consisted of 180 subjects, aged 37.1 ± 15.7 years, 66 males (36.7%) and 114 females (63.3%), presenting consecutively as new patients seeking routine dental care (not emergency care) at the University of Seville, Faculty of Dentistry, in the years 2002 and 2003. The criteria for inclusion in the study were that the patients should be attending for the first time. Patients younger than 18 years and patients having less than eight remaining teeth were excluded. The scientific committee of the Dental Faculty approved the study and all the patients gave written informed consent.

Radiographic examination

All participants underwent a full-mouth radiographic survey consisting of 14 periapical radiographs. All radiographs were taken with a Throphy CCX X-ray unit (Trophy Radiologie – 94300, Vincennes, France) and processed manually by two experienced dental assistants. Two experienced radiographers using the long-cone paralleling technique, setting of 70 kV, 10 mA, a film-focus distance of 28 cm, and Ultra Speed film (Eastman Kodak, Rochester, NY, USA), took all periapical radiographs.

Radiographic evaluation

From the full-mouth radiographic survey all root filled teeth, excluding third molars, were recorded according to the FDI nomenclature. Teeth were categorized as root filled teeth if they had been filled with a radiopaque material in the pulp chamber and/or in the root canal(s). In the root filled teeth the parameters listed in Table 1 were assessed. The periapical status was assessed using the 'Periapical Index' (PAI) score (Ørstavik *et al.* 1986), recorded for each one of the roots. The worst score of all roots was taken to represent PAI score for multirooted teeth. A score greater than 2 (PAI > 2) was considered to be a sign of periapical pathology (Ørstavik *et al.* 1986).

Observer

One observer with 6 years of clinical experience in endodontics examined the radiographs. The method of viewing the radiographs was standardized; films were examined in a darkened room using an illuminated viewer box with magnification (3.5×) whilst mounted in a cardboard slit to block off ambient light emanating from the viewer. Before evaluation, the observer participated in a calibration course for the PAI system, which consisted of 100 radiographic images of teeth (kindly provided by Dr Ørstavik), some root filled and some not. Each tooth was assigned to one of the five PAI scores using visual references (also provided by Dr Ørstavik) for the five categories within the scale. After scoring the teeth, the results were compared with a 'gold standard atlas', and Cohen's κ was 0.71.

Intra-observer reproducibility was evaluated by the repeat scoring of 50 individuals' radiographs randomly selected. Before the second evaluation of the radiographs, the observer was recalibrated in the PAI system by scoring the 100 standard images. The intraobserver agreement test on PAI scores on the 50 patients produced a Cohen's κ of 0.77.

Statistical analysis

Diagnostic thresholds for the present study were (Table 1):

Table 1 Parameters recorded on root filled teeth

Parameters	Registrations and codes
Coronal restorations (filling and crown)	1 = Adequate (radiographically sealed) 2 = Inadequate (signs of overhangs or with open margins)
Adaptation of root filling	1 = Adequate in the coronal 1/2 of the root filling + adequate in the apical 1/2 of the root filling 2 = Adequate in the coronal 1/2 of the root filling + inadequate in the apical 1/2 of the root filling 3 = Inadequate in the coronal 1/2 of the root filling + adequate in the apical 1/2 of the root filling 4 = Inadequate in the coronal 1/2 of the root filling + inadequate in the apical 1/2 of the root filling
Length of root filling	1 = Root filling ending ≤3 mm from radiographic apex 2 = Root filling ending >3 mm from radiographic apex 3 = Pulpotomy, material seen only in the pulp chamber 4 = Flush, root filling ending at the radiographic apex 5 = Over-filling, root filling material seen in the periapical area
Periapical Index (Ørstavik *et al.* 1986)	1 = Normal periapical structures 2 = Small changes in bone structure 3 = Changes in bone structure with some mineral loss 4 = Periodontitis with well defined radiolucent area 5 = Severe periodontitis with exacerbating features

1. Adaptation of root filling to canal walls: adequate if no voids were present in the root filling; score 1 = adequate, and scores 2, 3 and 4 = inadequate.
2. Length of root filling: adequate if ending ≤3 mm from, or flush with, the radiographic apex; score 1 and 4 = adequate, and score 2, 3 and 5 = inadequate.
3. Periapical bone: score 1 and 2 = sound, and score 3, 4 and 5 = diseased (AP).

Raw data were entered in Excel® (Microsoft Corporation, Redmond, WA, USA). All analyses were done in an SPSS environment (Version 11; SPPS, Inc., Chicago, IL, USA). Logistic regression was used for statistical evaluation of the results. Odds ratio with 95% confidence interval (CI) was calculated.

Results

The total number of root filled teeth was 93; AP was present in 60 teeth (64.5%). Table 2 shows the relationship between the adaptation of root filling to canal walls and periapical status. Root filled teeth without voids had AP in 55.3% of cases, whereas if voids were detected, disease was present in 73.9% of the teeth ($P = 0.063$; odds ratio = 2.29; CI = 0.96–5.50).

The relationship between the length of the root filling and periapical status is shown in Table 3. Apical periodontitis was found in 55.1% of teeth with adequate length of root filling, whereas if the filling was too short or long, periapical lesions were present in 75% of teeth ($P = 0.048$; odds ratio = 2.44; CI = 1.01–5.92).

Table 2 Adaptation of fillings to the canal walls and the relation to the periapical status, percentage for healthy/diseased

Treatment	Total no. of teeth	Healthy (%)	Diseased (%)
Adequate adaptation	47	21 (44.7)	26 (55.3)
Inadequate adaptation	46	12 (26.1)	34 (73.9)
Total	93	33 (35.5)	60 (64.5)

Logistic regression: $P = 0.063$.

Table 3 Length of fillings and the relation to the periapical status, percentage for healthy/diseased

Treatment	Total no. of teeth	Healthy (%)	Diseased (%)
Adequate length	49	22 (44.9)	27 (55.1)
Inadequate length	44	11 (25.0)	33 (75.0)
Total	93	33 (35.5)	60 (64.5)

Logistic regression: $P = 0.048$.

The relationship between the quality of the coronal restoration and periapical status is presented in Table 4. Approximately 50% of the teeth with adequate coronal restorations had AP, whereas if the coronal restoration was inadequate, disease was present in 71.7% of the teeth ($P = 0.054$; odds ratio = 2.38; CI = 0.98–5.76).

Teeth that had root fillings with adequate length, as well as adequate adaptation of the filling to the canal

Table 4 Quality of coronal restoration on root filled teeth and the relation to the periapical status, percentage for healthy/diseased

Treatment	Total no. of teeth	Healthy (%)	Diseased (%)
Adequate coronal restoration	33	16 (48.5)	17 (51.5)
Inadequate coronal restoration	60	17 (28.3)	43 (71.7)
Total	93	33 (35.5)	60 (64.5)

Logistic regression: $P = 0.054$.

Table 5 Quality of combined treatment and the relation to the periapical status, percentage for healthy/diseased

Treatment	Total no. of teeth	Healthy (%)	Diseased (%)
Adequate adaptation + length	32	17 (53.1)	15 (46.9)[a]
Any other quality combination	61	16 (26.2)	45 (73.8)
Total	93	33 (35.5)	60 (64.5)
Inadequate adaptation + length	29	7 (24.1)	22 (75.9)[b]
Any other quality combination	64	26 (40.6)	38 (59.4)
Total	93	33 (35.5)	60 (64.5)
Adequate adaptation + length + crown	16	11 (68.9)	5 (31.3)[c]
Any other quality combination	77	22 (28.6)	55 (71.4)
Total	93	33 (35.5)	60 (64.5)
Inadequate adaptation + length + crown	20	5 (25.0)	15 (75.0)[b]
Any other quality combination	73	28 (38.3)	45 (61.6)
Total	93	33 (35.5)	60 (64.5)

[a]Logistic regression: $P = 0.011$.
[b]Logistic regression: $P > 0.05$.
[c]Logistic regression: $P = 0.004$.

walls were tested against any other combination of treatment quality (adequate length/inadequate adaptation, inadequate length/adequate adaptation, and inadequate length/inadequate adaptation) (Table 5). Both length and adaptation was found to be adequate in 32 teeth (34.4%), and 46.9% of these teeth had periapical lesions, significantly less than any other combination ($P = 0.011$; odds ratio = 3.19; CI = 1.30–7.83). The 29 teeth with both inadequate length and adaptation of root fillings were compared with the other combinations of treatment quality; 75.9% of these teeth had periapical lesions whereas periapical disease was present in 59.4% of the other teeth ($P = 0.128$).

Finally, all three-quality parameters were combined. Coronal restoration, filling adaptation, and length were found to be adequate only in 16 teeth (17.2%), and less than one-third of these teeth had AP (Table 5). When tested against any other combination of the quality parameters, this was significantly better than any other combination ($P = 0.004$; odds ratio = 5.50; CI = 1.71–17.67). In 20 teeth both the coronal and the root filling were inadequate, and when they were tested against any other combination of the quality parameters, these teeth had more periapical lesions (75%) ($P = 0.27$).

The multivariate logistic regression analysis combining two independent variables: (i) quality of root filling (both adaptation and length), and (ii) quality of coronal restoration, for the variable 'periapical status' (Table 6), demonstrated that quality of root filling ($P = 0.028$; odds ratio = 2.81; CI = 1.12–7.06) affected significantly the periapical status, but quality of the coronal restoration had no effect ($P = 0.15$; odds ratio = 1.97; CI = 0.78–4.95).

Discussion

The study population has been described previously, as well as the possible causes contributing to the high proportion (65%) of apical lesions in connection with root filled teeth at the disease threshold utilized (Jiménez-Pinzón *et al.* 2004). Previous epidemiological surveys have also shown a high prevalence of AP in connection with root filled teeth, ranging between 22 and 61% (Saunders *et al.* 1997, Weiger *et al.* 1997, Marques *et al.* 1998, Sidaravicius *el al.* 1999, Kirkevang *et al.* 2001, Dugas *et al.* 2003).

In the present study the quality of the adaptation to the root canal walls, the length of the root filling, and the quality of the coronal restoration were evaluated in relation to periapical status. The limitations of the method used included the following: radiographic

Table 6 Logistic regression analyses of the influence of two independent variables, the quality of endodontic filling (QEF) and the quality of the coronal restoration (QCR), on the explicative variable 'periapical status'

	B	ET	Wald	gl	*P*	Exp(*B*)	95% CI inf. limit	95% CI sup. limit
QCR	0.679	0.470	2.090	1	0.148	1.973	0.785	4.954
QEF	1.034	0.470	4.846	1	0.028	2.811	1.120	7.058
Constant	−1.245	0.335	13.841	1	0.000	0.288		

Exp(B) = odds ratio.

assessment only, and small sample size of root filled teeth, i.e. only 93 in the 180 patients studied. Thus, the results of this study and its conclusions should be drawn with caution.

A number of reports on the effects of root canal treatment on periapical status have been published. The population included in these studies were not homogeneous, and the methods evaluating the quality of root filling and periapical status also differed, nevertheless, all used radiographs. However, it is impossible to assess the quality of root canal debridement procedures from radiographs. The radiographic appearance of a filled canal is only a gross sign of its sealing capacity (Weiger *et al.* 1997).

In the present study approximately 49% of the root fillings were not adapted to the canal wall, and of these, 73.9% had AP. Similar results have been reported in previous studies: percentages between 30 and 60% of root filling showing void have been reported, and approximately 60–70% of these had AP (Eriksen *et al.* 1988, Eriksen & Bjertness 1991, Kirkevang *et al.* 2000, Chugal *et al.* 2003, Dugas *et al.* 2003).

The results of the present study indicate that the length of the root filling was significantly associated with periapical status. A total of 53% of the root fillings had an adequate length, and of these, 55.1% had AP ($P = 0.048$). On the contrary, when the length was shorter or longer, 75% of the teeth had periapical lesion. Studies in other European populations have shown that approximately 10–46% of the teeth with adequate length of root filling had AP (Eriksen *et al.* 1988, Eriksen & Bjertness 1991, De Cleen *et al.* 1993, Saunders *et al.* 1997, Kirkevang *et al.* 2000, Dugas *et al.* 2003). Combining both criteria, lateral seal and adaptation to root canal walls, only 34% of the root filled teeth fulfilled the criteria for an acceptable root canal filling. Other published studies also show an acceptable root canal filling rate in 30–40% of teeth (Ödesjö *et al.* 1990, Weiger *et al.* 1997, De Moor *et al.* 2000, Dugas *et al.* 2003).

The quality of the seal created by the coronal restoration is one of the factors significantly associated with failure of endodontic treatment (Sidaravicius *et al.* 1999, Tronstad *et al.* 2000). Moreover, Ray & Trope (1995) found that the technical quality of the coronal restoration was even more important for periapical health than the quality of endodontic treatment. However, Tronstad *et al.* (2000) demonstrated that if the root filling was inadequate, it did not matter whether the coronal restoration was adequate or inadequate, the tooth would still have a poor prognosis. Moreover, Ricucci *et al.* (2000) reported that exposure of root fillings to the oral microbiota was not significantly correlated with periradicular status.

The results of the present study showed that the quality of the coronal restoration influenced, but not significantly, the periapical status, since as much as 71.7% of the teeth with inadequate coronal restoration had AP. Other investigators (Kirkevang *et al.* 2000, Dugas *et al.* 2003) found a significant correlation between the radiographic quality of the coronal restoration and the periapical status of root filled teeth, but not as pronounced as Ray & Trope (1995).

When the quality of the root fillings and the quality of coronal restoration were combined, an even more pronounced pattern was seen. When both were of high quality, 68.9% of the teeth had healthy periapical bone ($P = 0.004$). Kirkevang *et al.* (2000) and Dugas *et al.* (2003) found similar percentages: 70 and 81%, respectively. This strongly indicates that both factors play important roles in obtaining an efficient seal of root canal. However, the results of the present study suggest that an adequate root filling had a more decisive impact on the outcome of treatment. Multivariate logistic regression analysis provide a significant odds ratio of 2.81 ($P = 0.028$) for adequate root filling, and a non-significant odds ratio of 1.97 ($P = 0.148$) for adequate coronal restoration, corroborating the results reported by other authors (Sidaravicius *et al.* 1999, Kirkevang *et al.* 2000, Tronstad *et al.* 2000, Dugas *et al.* 2003).

Conclusions

Apical periodontitis was present in 64.5% of root filled teeth. Within the limitations of this study, the results indicate that an adequate root filling had a more substantial impact on the outcome of treatment than the quality of coronal restorations. Both inadequate root filling and coronal restorations were associated with an increased incidence of AP. On the contrary, adequate root fillings and coronal restorations significantly reduced the incidence of AP. Many root canal treatments were technically unsatisfactory and substantial efforts must be made to improve the standard of endodontic treatment in Spain.

References

Boucher Y, Matossian L, Rilliard F, Machtou P (2002) Radiographic evaluation of the prevalence and technical quality of root canal treatment in a French subpopulation. *International Endodontic Journal* **35**, 229–38.

Çaliskan MK, Sen BH (1996) Endodontic treatment of teeth with apical periodontitis using calcium hydroxide: a long-term study. *Endodontics and Dental Traumatology* **12**, 215–21.

Chugal NM, Clive JM, Spangberg LSW (2003) Endodontic infection: some biologic and treatment factors associated with outcome. *Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontics* **96**, 81–90.

De Cleen MJ, Schuurs AH, Wesselink PR, Wu MK (1993) Periapical status and prevalence of endodontic treatment in an adult Dutch population. *International Endodontic Journal* **26**, 112–9.

De Moor RJ, Hommez GM, De Boever JG, Delme KI, Martens GE (2000) Periapical health related to the quality of root canal treatment in a Belgian population. *International Endodontic Journal* **33**, 113–20.

Dugas NN, Lawrence HP, Teplitsky PE, Pharoah MJ, Friedan S (2003) Periapical health and treatment quality assessment of root-filled teeth in two Canadian populations. *International Endodontic Journal* **36**, 181–92.

Eriksen HM (1998) Epidemiology of apical periodontitis. In: Orstavik D, Pitt Ford TR, eds. *Essential Endodontology. Prevention and Treatment of Apical Periodontitis*. London: Blackwell Science Ltd, pp. 179–91.

Eriksen HM, Bjertness E (1991) Prevalence of apical periodontitis and results of endodontic treatment in middle-aged adults in Norway. *Endodontics and Dental Traumatology* **7**, 1–4.

Eriksen HM, Bjertness E, Ørstavik D (1988) Prevalence and quality of endodontic treatment in an urban adult population in Norway. *Endodontics and Dental Traumatology* **4**, 122–6.

Eriksen HM, Kirkevang L-L, Petersson K (2002) Endodontic epidemiology and treatment outcome: general considerations. *Endodontic Topics* **2**, 1–9.

Friedman S (1998) Treatment outcome and prognosis of endodontic therapy. In: Orstavik D, Pitt Ford TR, eds. *Essential Endodontology. Prevention and Treatment of Apical Periodontitis*. London: Blackwell Science Ltd, pp. 367–401.

Iqbal MK, Johansson AA, Akeel RF, Bergenholtz A, Omar R (2003) A retrospective analysis of factors associated with periapical status of restored endodontically treated teeth. *International Journal of Prosthodontics* **16**, 31–8.

Jiménez-Pinzón A, Segura-Egea JJ, Poyato-Ferrera M, Velasco-Ortega E, Ríos-Santos JV (2004) Prevalence of apical periodontitis and frequency of root filled teeth in an adult Spanish population. *International Endodontic Journal* **37**, 167–173.

Kirkevang LL, Ørstavik D, Hörsted-Bindslev P, Wenzel A (2000) Periapical status and quality of root fillings and coronal restorations in a Danish population. *International Endodontic Journal* **33**, 509–15.

Kirkevang LL, Hörsted-Bindslev P, Ørstavik D, Wenzel A (2001) Frequency and distribution of endodontically treated teeth and apical periodontitis in an urban Danish population. *International Endodontic Journal* **34**, 198–205.

Lupi-Pegurier L, Bertrand M-F, Muller-Bolla M, Rocca JP, Bolla M (2002) Periapical status, prevalence and quality of endodontic treatment in an adult French population. *International Endodontic Journal* **35**, 690–7.

Marques MD, Moreira B, Eriksen HM (1998) Prevalence of apical periodontitis and results of endodontic treatment in an adult, Portuguese population. *International Endodontic Journal* **31**, 161–5.

Ödesjö B, Hellden L, Salonen L, Langeland K (1990) Prevalence of previous endodontic treatment, technical standard and occurrence of periapical lesions in a randomly selected adult, general population. *Endodontics and Dental Traumatology* **6**, 265–72.

Ørstavik D (1996) Time course and risk analyses of the development and healing of chronic apical periodontitis in man. *International Endodontic Journal* **29**, 150–5.

Ørstavik D, Hörsted-Binslev P (1993) A comparison on endodontic treatment results at two dental schools. *International Endodontic Journal* **26**, 348–54.

Ørstavik D, Kerekes K, Eriksen HM (1986) The periapical index: a scoring system for radiographic assessment of apical periodontitis. *Endodontics and Dental Traumatology* **2**, 20–34.

Ray HA, Trope M (1995) Periapical status of endodontically treated teeth in relation to the technical quality of the root filling and the coronal restoration. *International Endodontic Journal* **28**, 12–8.

Ricucci D, Gröndahl K, Bergenholtz G (2000) Periapical status of root-filled teeth to the oral environment by loss of restoration or caries. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics* **90**, 354–9.

Saunders WP, Saunders EM, Sadiq J, Cruickshank E (1997) Technical standard of root canal treatment in an adult Scottish subpopulation. *British Dental Journal* **182**, 382–6.

Sidaravicius B, Aleksejuniene J, Eriksen HM (1999) Endodontic treatment and prevalence of apical periodontitis in an adult population of Vilnius, Lithuania. *Endodontics and Dental Traumatology* **15**, 210–5.

Sjögren U, Hägglund B, Sundqvist G, Wing K (1990) Factors affecting the long-term results of endodontic treatment. *Journal of Endodontics* **16**, 498–504.

Strindberg LZ (1956) The dependence of results of pulp therapy on certain factors. *Acta Odontologica Scandinavica* **14**, 1–175.

Tronstad L, Absjornsen K, Doving L, Pedersen I, Eriksen HM (2000) Influence of coronal restorations on the periapical health of endodontically treated teeth. *Endodontics and Dental Traumatology* **16**, 218–21.

Weiger R, Hitzler S, Hermle G, Löst C (1997) Periapical status, quality of root canal fillings and estimated endodontic treatment needs in an urban German population. *Endodontics and Dental Traumatology* **13**, 69–74.