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Australian Endodontic Journal

ORIGINAL RESEARCH

The Role of Root Canal Treatment in Alleviating Endodontic Pain-Induced Asymmetry and Restoring Muscle Balance: A Self-Controlled Prospective Observational Study

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Received: 29 May 2025 | **Revised:** 27 June 2025 | **Accepted:** 11 July 2025

Funding: The authors received no specific funding for this work.

Keywords: masticatory laterality | root canal treatment | symptomatic apical periodontitis | ultrasonography

ABSTRACT

This study aimed to investigate whether root canal treatment (RCT) restores muscle symmetry by measuring the thickness of masseter and anterior temporalis muscles using ultrasonography. A self-controlled prospective observational study was conducted with patients experiencing moderate-to-severe endodontic pain and masticatory laterality. Ultrasonographic measurements of masseter and anterior temporalis muscles were taken at rest and during contraction before RCT, 1 week after treatment and 3 months post-treatment. An asymmetry index was calculated to evaluate changes in muscle thickness over time. Significant increases in masseter muscle thickness were observed on the painful side, both at rest and during contraction, while the control side showed a significant increase only during contraction. No statistically significant changes were observed in anterior temporalis muscle thickness, although a similar trend was noted. The asymmetry indices decreased significantly over time, approaching zero by the third month. RCT effectively reduces muscle asymmetry caused by endodontic pain, restoring balanced masticatory function.

Trial Registration: ClinicalTrials.gov identifier: NCT06853028

1 | Introduction

Among the leading causes of dental visits, odontogenic pain is highly prevalent, with endodontic pain playing a significant role [1]. Endodontic pain typically arises from the pulp tissue's response to external stimuli such as dental caries, trauma or restorative and prosthetic procedures [2]. It can also emerge following endodontic treatment due to complications, including the acute exacerbation of chronic lesions, incomplete removal of pulp tissue, inadequate canal preparation or irrigation, undetected extra canals, extrusion of root canal filling materials or leakage in permanent restorations [3, 4]. Symptomatic apical periodontitis (SAP) is a common inflammatory condition associated with endodontic pain, often resulting from infection or inflammation of the dental pulp and surrounding periapical tissues. This condition is characterised by severe pain, tenderness to percussion and discomfort during mastication, significantly impacting a patient's quality of life [5].

Regardless of its origin, odontogenic pain often radiates to various regions of the face and head, including the preauricular and auricular areas, and can mimic orofacial pain syndromes [6]. Research has demonstrated that odontogenic pain may radiate to other areas of the face and head, causing muscle pain, stiffness

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and secondary hyperalgesia in distant regions [7, 8]. This can result in painful chewing and altered chewing behaviour, with patients favouring the non-painful side, a condition known as masticatory laterality (or unilateral chewing) [9].

Over time, masticatory laterality can impose excessive mechanical loads on the temporomandibular joint (TMJ), leading to adaptive or degenerative changes in the joint and associated muscles, as well as wear in the articular eminence region [10]. Prolonged masticatory laterality has been associated with the development of masticatory muscle asymmetry. Asymmetry in masticatory muscles due to unilateral chewing habits can manifest even before the onset of temporomandibular disorders (TMDs). This asymmetry is characterised by altered muscle activity and coordination, which may predispose individuals to TMD. Early detection and intervention could potentially mitigate the progression to TMD [11].

Recent advancements underscore the necessity of a comprehensive approach to evaluating masticatory muscle disorders, considering the diverse etiologies and clinical manifestations of these conditions [12]. Imaging modalities such as ultrasonography (USG), computed tomography (CT), magnetic resonance imaging (MRI) and electromyography (EMG) have been utilised to assess the cross-sectional area and thickness of masticatory muscles [13–15]. Among these, USG has emerged as a reliable, non-invasive, cost-effective and reproducible technique for measuring the thickness and cross-sectional area of masticatory muscles in vivo. Additionally, its non-ionising nature and ease of application make it well-tolerated by patients in both medical and dental settings [16].

This self-controlled prospective observational study aims to evaluate muscle asymmetry in patients with masticatory laterality (unilateral chewing habits) due to moderate or severe endodontic pain in permanent maxillary and mandibular molars with SAP. The study involves measuring the thickness of the masseter and anterior temporalis muscles using ultrasonography at three time points: immediately before root canal treatment, and at 1 week and 3 months post-treatment.

The study hypothesises that masticatory laterality caused by endodontic pain, particularly in cases of SAP, results in measurable muscle asymmetry. Furthermore, it posits that root canal treatment, by restoring normal bilateral chewing function, will reduce this asymmetry, as evidenced by ultrasonographic measurements of the masseter and anterior temporalis muscles.

2 | Materials and Methods

2.1 | Study Design and Ethical Approval

This self-controlled prospective observational study was conducted between January 2024 and December 2024 at the Department of Endodontics and the Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Cukurova University. Ethical approval was granted by the Cukurova University Research Ethics Committee (meeting no: 144, decision no: 32, date: May 10, 2024).

2.2 | Participant Selection

This study included 11 females and 9 males aged 18–60 years who were systemically healthy and had permanent molars with symptomatic apical periodontitis. Informed written consent was obtained from all participants involved in the study.

2.3 | Inclusion Criteria

- Patients with masticatory laterality due to SAP pain for at least 30 days.
- First and second maxillary or mandibular molars with SAP due to deep caries.
- Teeth with moderate or severe pain according to the visual analogue scale (VAS) (no pain [0 mm], mild pain [1–3 mm], moderate pain [4–6 mm] and severe pain [7–10 mm]).
- Teeth that responded positively to percussion test.
- Teeth without periapical pathosis were included in the study.

2.4 | Exclusion Criteria

- Systemic conditions affecting muscle structure or function, such as neuromuscular or endocrine disorders.
- Non-endodontic odontogenic pain.
- Prior endodontic treatment of the relevant tooth within the last 30 days.
- History of trauma or surgery to the head, face or teeth within the last 6 months.
- Severe communication disorders or psychological issues.
- Inability to complete treatment in a single visit due to exudation or bleeding.
- Patients with masticatory laterality due to a missing tooth on any side of the dental arch.
- Patients who have painful teeth in opposite sides of the dental arch.
- Patients who have parafunctional habits including bruxism and clenching.
- According to the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) classification [17], patients diagnosed with any TMD subtype were excluded from the study. This exclusion criterion encompasses pain-related TMDs (myalgia, localised myalgia, myofascial pain, referred myofascial pain, arthralgia and headache attributed to TMD) as well as intra-articular disorders (disc displacement with or without reduction, degenerative joint disease and subluxation).

TMD form was filled out by all participants involved in the study. Then, these patients underwent TMD examination. The diagnosis of TMD was performed in accordance with the DC/

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TMD guidelines. Both Axis I (clinical conditions) and Axis II (psychosocial status and pain-related disability) evaluations were conducted. Items appraised concerned TMJ noises (crepitus and clicking), jaw movements/deviations, palpation/movement pain and pain locations. Headache attributed to TMD, arthralgia, myofascial pain, myofascial pain with referral, myalgia, local myalgia which are included in the pain-related TMD, and subluxation, degenerative joint disease, disc displacement disorders which are included in the intra-articular TMD were defined as TMD [17].

2.5 | Sample Size Calculation

The sample size for this study was determined based on data from a pilot study and calculated using G*Power 3.1 software. Effect sizes (Cohen's $f \geq 0.40$) were calculated for the changes in muscle thickness and asymmetry indices over time. Considering this effect size, with a significance level (α) of 0.05 and a desired power ($1-\beta$) of 0.85, the minimum required sample size for repeated measures ANOVA was calculated to be 18. To compensate for potential dropouts and maintain statistical power, the sample size was rounded up to 20 participants.

2.6 | Root Canal Treatment Protocol

All root canal treatment procedures were performed in a single visit by an experienced endodontist (K.G.). The teeth were anaesthetised using 4% articaine hydrochloride with 1:100000 epinephrine (Ultracain D-S; Sanofi, Paris, France), isolated with a rubber dam (Roeko; Coltène–Whaledent), and prepared under water cooling with diamond round and fissure burs (Frank Dental). The working length was established with a #10 K-type hand file (VDW GmbH) and an electronic apex locator (Morita Root ZX, Tokyo, Japan), confirmed with a periapical radiograph. After the root canals were shaped with a #15 K-type hand file, the mesiolingual, mesiobuccal and mesiodistal canals were prepared using the Reciproc Blue R25 (25/0.08) file (RB, VDW, Munich, Germany), while the distal and palatal canals were shaped with the Reciproc Blue R40 (40/0.06) file using the crown-down technique. The file was removed and cleaned at each insertion, and the canals were irrigated with 2 mL of 2.5% sodium hypochlorite (NaOCl) (Wizard; Rehber Kimya) solution with 30 gauge side-vented needles (NaviTips; Ultradent). These procedures were continued until the files reached the working length. Canal irrigation was completed by using 10 mL of 2.5% NaOCl between the insertions. The final irrigation was performed with 2 mL of 2.5% NaOCl, 2 mL of 17% ethylenediaminetetraacetic acid (EDTA) (EndoSolution; PPH Cerkamed) and 2 mL of distilled water. The canals were dried with paper points (President Dental) and filled using the cold lateral condensation technique with gutta-percha (President Dental) and AH Plus root canal sealer (Dentsply Maillefer, Ballaigues, Switzerland). The permanent restoration of the teeth was completed with composite resins (Z350; 3M ESPE, Sumare, SP, Brazil), and occlusal adjustments were performed. The adequacy of the root canal filling was confirmed using periapical radiography.

2.7 | Ultrasonography Procedures

Ultrasound measurements were performed in the Department of Oral and Maxillofacial Radiology at the Faculty of Dentistry, Cukurova University, using a standardised protocol. The masseter and anterior temporalis muscle thicknesses (in millimetres, mm) of the patients were measured bilaterally using a high-frequency linear scanning probe (7 MHz) in B-mode of the Clarius Mobile Health ultrasound device (Vancouver, Canada). All scanning and measurement procedures were performed by the same oral and maxillofacial radiologist (İ.G.A.). The researcher's calibration was evaluated with the baseline measurements of 10 volunteers who were not included in the study. Muscle thickness measurements of the volunteers were performed at 1-week intervals. To verify the calibration and consistency in muscle thickness measurement, the intraclass correlation coefficient (ICC) was calculated for intra-observer repeatability. The ICC value was equal to 0.92, and excellent agreement was observed.

Muscle thickness measurements were performed with the ultrasound device immediately before RCT, 1 week after and 3 months after the treatment. Imaging was performed with the participants in an upright sitting position, and the Frankfurt horizontal plane was parallel to the ground. To avoid artefacts and oblique views, the probe was positioned perpendicular to the skin surface. A generous amount of water-based gel was applied between the probe and the skin surface to help the sound waves move efficiently between the probe and the tissue and prevent air gaps between the tissue and the probe.

The bilateral measurements of the masseter and anterior temporalis muscle thicknesses were obtained simultaneously on the screen using the distance measurement feature of the ultrasound device, by freezing the optimum image captured at the thickest part of the muscles at rest and maximum contraction (Figure 1). Masseter muscle thickness was measured at the intersection of a vertical line descending from the inferior border of the zygomatic arch and a horizontal plane passing through the midpoint of the mandibular ramus, following the validated protocol of Lin et al. [18]. Similarly, anterior temporalis muscle thickness was measured at the point where a vertical line drawn anterior to the hairline intersected the deepest part of the temporal fossa.

Symmetric changes in muscle thickness were measured on both the painful side and the non-painful, chewing side (control group) of the patient. As no established formula exists to calculate muscle thickness asymmetry, the asymmetry index was adapted from Naeije et al. [19] formula for muscle activity between the right and left sides:

$$\text{Asymmetry Index} = (\text{Thicker muscle thickness} - \text{Thinner muscle thickness}) / (\text{Thicker muscle thickness} + \text{Thinner muscle thickness}) \times 100$$

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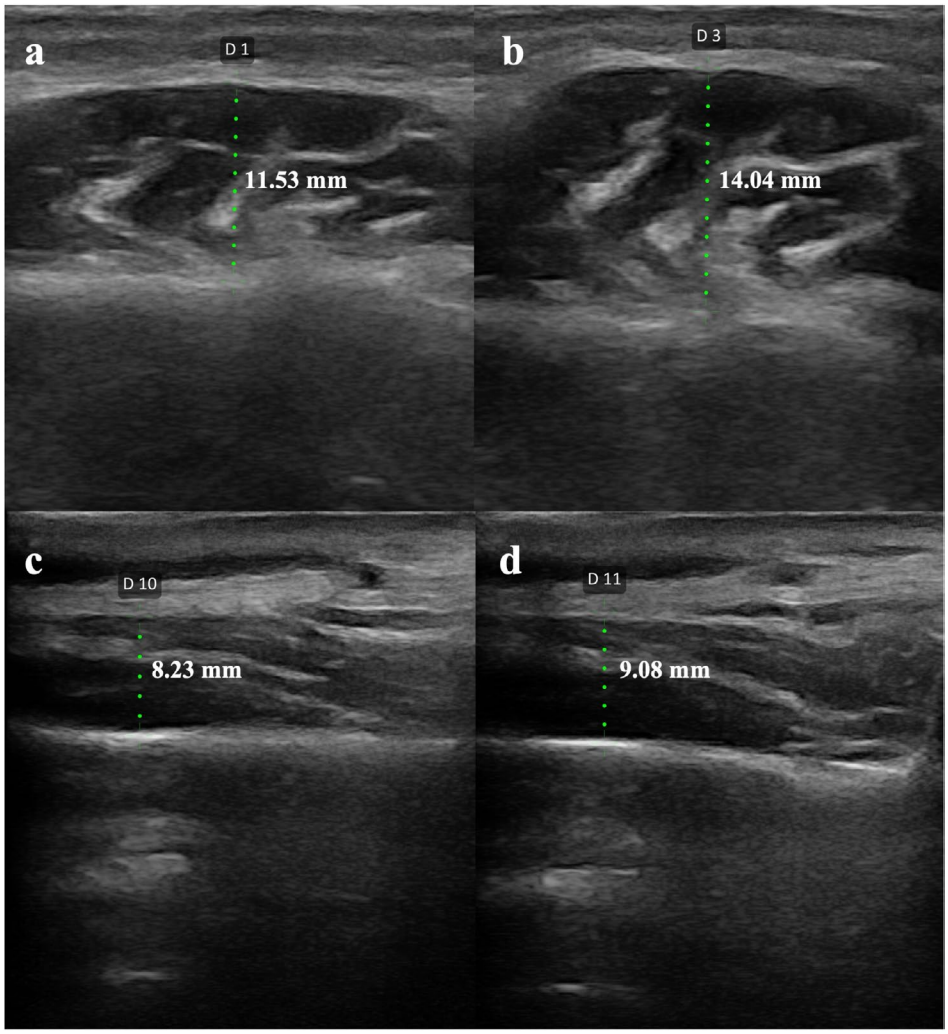


FIGURE 1 | Cross-sectional thicknesses of the masseter and anterior of temporalis muscles. (a) Relaxed state masseter; (b) contracted state masseter; (c) relaxed state anterior of temporalis; and (d) contracted state anterior of temporalis.

In this study, the original formula was modified to use muscle thickness measurements instead of muscle activity, as applied in the study by Alkaya et al. [20].

$$\text{Asymmetry-Index} = \left[(\text{Control-Side} - \text{Painful-Side})/(\text{Control-Side} + \text{Painful-Side})\right] \times 100$$

In this index, a value approaching zero indicates a reduction in the difference between bilateral muscle thicknesses, thus reflecting improved muscle symmetry. Positive values suggest greater thickness on the control (non-painful) side, while negative values indicate increased thickness on the painful side. Therefore, a progressive shift toward zero over time denotes a restoration of functional balance in the masticatory muscles.

To minimise measurement errors, each measurement was repeated three times at 5-min intervals. The average of the three measurements was used for statistical analysis. The same measurement protocol was repeated in each evaluation period.

2.8 | Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics software 20.0 (IBM Corp., Armonk, NY). The intra-observer reliability of muscle thickness measurements was assessed using the ICC. The level of significance was set at $p < 0.05$. Data were summarised as mean ± standard deviation or median (minimum–maximum). The Shapiro–Wilk test was used to assess the normality of the distribution of variables. Parametric tests were applied for comparisons when all parameters met the assumption of normality; otherwise, non-parametric tests were used. The Mann–Whitney *U* test was performed to compare the ages between the patients. The Friedman test or one-way ANOVA test was employed to evaluate time-dependent changes in muscle thickness measurements and asymmetry indices. For post hoc analyses, the Bonferroni method was used for pairwise comparisons if the Friedman test yielded significant results. If the one-way ANOVA test was significant, Tukey HSD or Games–Howell tests were applied depending on the homogeneity of variances. All graphs were generated using the Python programming language.

3 | Results

A total of 28 teeth were evaluated for eligibility. The study included 20 teeth from patients who met the inclusion criteria and accepted treatment. Of the 20 teeth that received RCT, 12 were

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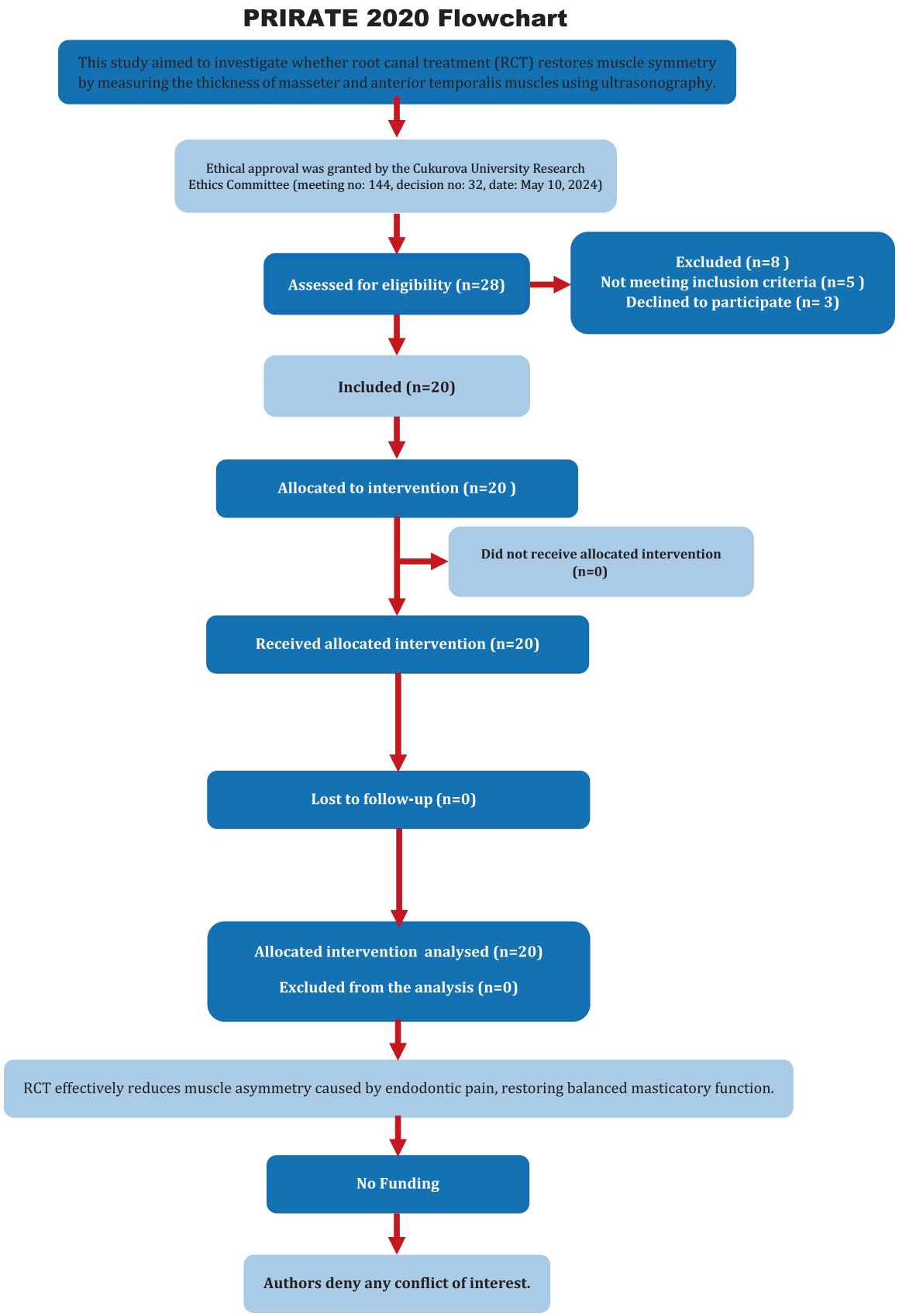


FIGURE 2 | The flowchart of participants throughout the trial. From: V. Nagendrababu, H. F. Duncan, L. Bjørndal, T. Kvist, E. Priya, J. Jayaraman, S. J. Pulikkotil, M. Pigg, D. K. Rechenberg, M. Vaeth, and P. Dummer, "PRIRATE 2020 Guidelines for Reporting Randomized Trials in Endodontics: A Consensus-Based Development," *International Endodontic Journal* (2020), https://doi.org/10.1111/iej.13294. For further details, visit: http://pride-endodonticguidelines.org/prirate/.

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permanent mandibular molars and 8 were permanent maxillary molars. No patients were lost to follow-up (Figure 2). There was no statistically significant difference in mean age between female and male patients ($p > 0.05$) (Table 1).

To verify calibration and consistency in muscle thickness measurements, the intra-observer repeatability was assessed using the ICC. The ICC value was 0.92, indicating excellent agreement ($p < 0.001$).

The thickness of the masseter muscle on the control side exhibited a non-significant decrease in the resting position, whereas a significant increase over time was observed in the contracted position (Table 2). As illustrated in Figure 3, a significant increase in masseter muscle thickness in the contracted position was evident on the control side by the first week. On the painful side, masseter muscle thickness showed a significant increase over time in both resting and contracted positions (Table 2).

For the temporalis muscle, no statistically significant time-dependent changes were observed in thickness, regardless of position or side (control or painful). However, as shown in Figure 3, the temporalis muscles exhibited a time-dependent trend similar to that of the masseter muscle, despite the lack of statistical significance. The asymmetry indices for both masseter and temporalis muscle thicknesses significantly decreased over time, reaching values close to zero by the third month (T3) (Table 3, Figure 4).

TABLE 1 | Patient demographic data.

	Female (*n*=11)	Male (*n*=9)	Total (*n*=20)	*p**
Age (mean ± SD)	30.6 ± 11.3	33.4 ± 9.8	32.4 ± 8.2	0.656

*Mann–Whitney *U* test.

4 | Discussion

To the best of our knowledge this study is the first to investigate muscle asymmetry in patients with masticatory laterality due to SAP and to evaluate whether RCT can restore muscle balance. Using USG, we assessed changes in the masseter and anterior temporalis muscles at rest and during contraction before and after RCT. Our findings demonstrate that endodontic pain leads to significant muscle asymmetry, which progressively resolves following treatment, supporting the

TABLE 2 | The time-dependent changes in the thickness (mm) of the masseter and temporalis muscles.

		T1	T2	T3	*p*
Masseter					
Control	RP[a]	12.73 ± 1.78	12.44 ± 1.75	12.06 ± 1.64	0.477
		12.49 (10.43–15.71)	12.39 (10.21–15.57)	12.07 (10.05–15.03)	
	CP[b]	13.32 ± 1.79[c,d]	14.52 ± 2.02[d]	14.7 ± 2.12	**< 0.001***
		12.93 (11.01–15.98)	14.2 (12.06–17.88)	14.34 (12.22–18.33)	
Painful	RP[b]	10.77 ± 1.7[c,d]	11.24 ± 1.71[d]	12.25 ± 1.69	**< 0.001***
		10.41 (8.1–13.57)	10.85 (8.72–14.46)	11.77 (10.12–15.34)	
	CP[b]	11.49 ± 1.72[c,d]	13.15 ± 2[d]	14.79 ± 2.29	**< 0.001***
		11.11 (9.24–14.65)	12.47 (10.62–17.11)	14.3 (12.47–18.95)	
Temporalis					
Control	RP[a]	9.14 ± 0.99	8.92 ± 0.9	8.77 ± 0.91	0.459
		9.17 (7.72–10.84)	9.03 (7.66–10.54)	8.94 (7.51–10.34)	
	CP[a]	9.51 ± 1	9.78 ± 1.03	9.75 ± 0.94	0.647
		9.65 (7.94–11.48)	9.9 (8.04–11.6)	9.81 (8.16–11.52)	
Painful	RP[a]	8.56 ± 0.95	8.68 ± 0.95	8.76 ± 0.94	0.782
		8.67 (7.17–10.17)	8.82 (7.37–10.27)	8.85 (7.4–10.39)	
	CP[a]	9.05 ± 0.94	9.54 ± 1.02	9.81 ± 1.05	0.064
		9.23 (7.53–10.89)	9.55 (7.99–11.34)	9.86 (8.07–11.7)	

Note: The thickness values are presented in millimetres (mm). [c,d]Significant difference ($p < 0.05$) for pairwise comparisons.
Abbreviations: CP, Contracted position; RP, Rest position; T1, Immediately before RCT; T2, 1 week after RCT; T3, 3 months after RCT.
[a]ANOVA.
[b]Friedman test.
[c]Compared to 1st week.
[d]Compared to 3rd month.
Bold values indicate statistically significant results based on ANOVA or Friedman tests ($p < 0.001$).

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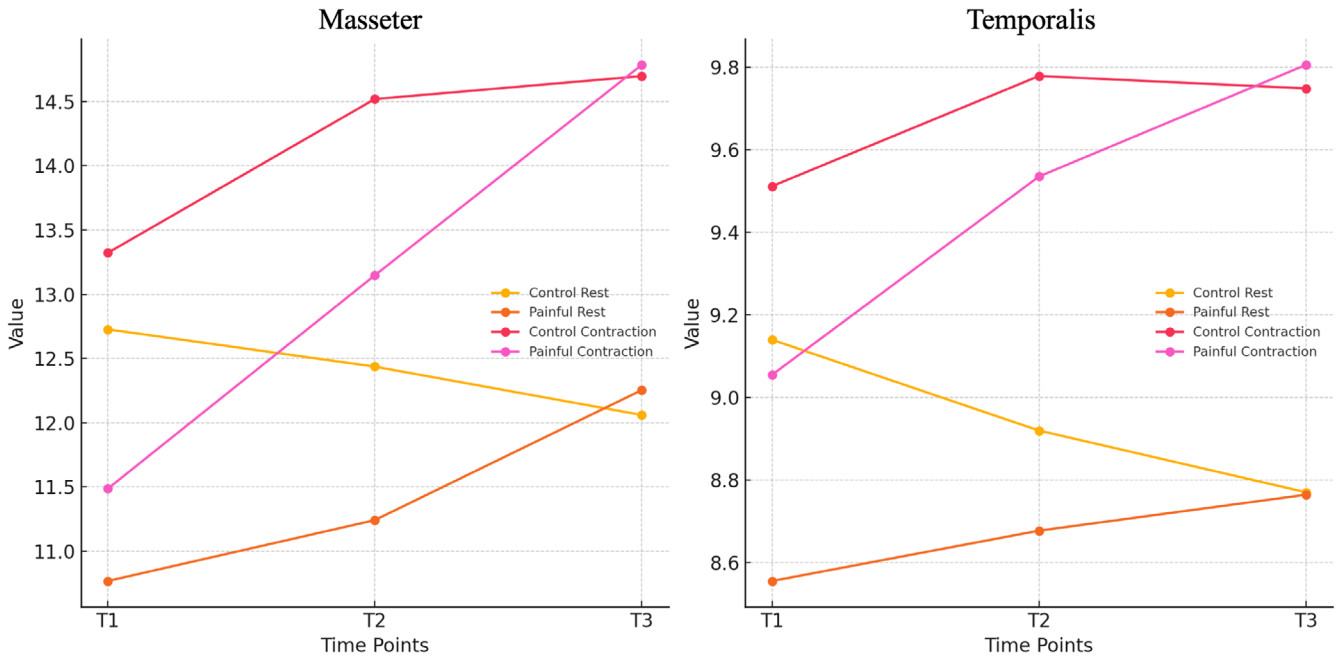


FIGURE 3 | The time-dependent changes in the thickness of the masseter and temporalis muscles (T1, Immediately before RCT; T2, 1 week after RCT; T3, 3 months after RCT).

TABLE 3 | The time-dependent changes in the asymmetry index for the masseter and temporalis muscles.

	T1	T2	T3	*p*
Masseter				
RP[b]	8.44 ± 2.59[c,d]	5.11 ± 2.22[d]	−0.8 ± 1.62	< 0.001*
	7.53 (4.94 to 12.57)	4.76 (2.42 to 9.8)	−0.98 (−3.55 to 2.65)	
CP[a]	7.48 ± 1.88[c,d]	5.03 ± 2.22[d]	−0.24 ± 1.58	< 0.001*
	7.36 (4.34 to 10.94)	4.63 (2.2 to 9.54)	−0.29 (−2.58 to 3.88)	
Temporalis				
RP[a]	3.32 ± 0.71[c,d]	1.42 ± 0.78[d]	0.05 ± 0.75	< 0.001*
	3.3 (1.98 to 4.63)	1.41 (0.18 to 2.53)	0.08 (−1.53 to 1.33)	
CP[b]	2.46 ± 0.45[c,d]	1.27 ± 0.82[d]	−0.24 ± 0.73	< 0.001*
	2.62 (1.04 to 2.91)	1.21 (−0.27 to 2.69)	−0.34 (−1.17 to 1.34)	

Note: [c,d]Significant difference ($p < 0.05$) for pairwise comparisons.
Abbreviations: AI, Asymmetry index; CP, Contracted position; RP, Rest position; T1, Immediately before RCT; T2, 1 week after RCT; T3, 3 months after RCT.
[a]ANOVA.
[b]Friedman test.
[c]Compared to 1st week.
[d]Compared to 3rd month.
*$p < 0.001$.

hypothesis that masticatory laterality induced by pain disrupts muscle function and that its resolution restores neuromuscular balance.

The results revealed a significant increase in masseter muscle thickness on the painful side over time, both in resting and contracted states, following RCT. Interestingly, on the control side, masseter thickness increased significantly in the contracted state but not at rest. These findings suggest that endodontic pain-induced masticatory laterality influences muscle morphology, likely through compensatory mechanisms. Previous studies have shown that muscle hypertrophy occurs in response to increased functional loading on one side, while disuse atrophy may develop on the opposite side [21]. In contrast, the anterior temporalis muscle did not exhibit statistically significant changes, possibly due to its stabilising function in mastication or individual variations in adaptive responses [22].

A key finding was the progressive reduction in muscle asymmetry indices over time, with values nearly returning to zero by the third month post-treatment, indicating restored neuromuscular balance. These results highlight the clinical importance of managing endodontic pain not only for pain relief but also for preventing neuromuscular dysfunction. Unlike tooth extraction, which may compromise chewing efficiency and reinforce masticatory laterality, RCT preserves the natural tooth, allowing for the maintenance of bilateral chewing and occlusal stability.

Endodontic pain and TMD-related symptoms frequently coexist, complicating differential diagnosis and treatment outcomes. Nixdorf et al. reported that in 42% of cases, residual pain following RCT was at least partially attributed to TMD [23]. Given this overlap, our findings suggest that timely intervention to eliminate pain-induced masticatory laterality may help prevent neuromuscular imbalances associated with TMD. Additionally, some studies in the literature highlight that pulpal inflammation triggers peripheral and central sensitisation in the trigeminal system, leading to neuroplastic changes such as glial activation and upregulation of pro-nociceptive markers (e.g., TRPV1, c-Fos), which may exacerbate or initiate TMD pain. Our observation that endodontic pain-induced masticatory laterality leads to measurable muscle asymmetry, which resolves

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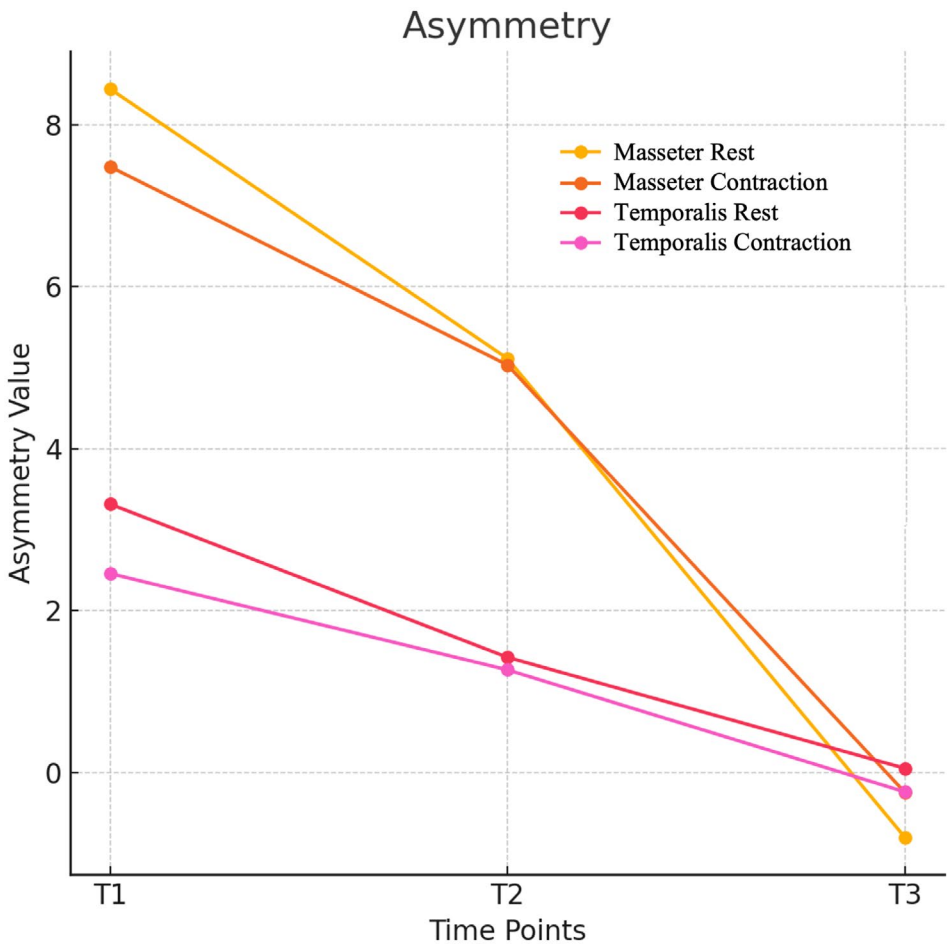


FIGURE 4 | The time-dependent changes in the asymmetry index for the masseter and temporalis muscles (T1, Immediately before RCT; T2, 1 week after RCT; T3, 3 months after RCT).

following RCT, further supports the hypothesis that eliminating the primary odontogenic pain source can mitigate secondary TMD symptoms [24–28].

These findings are consistent with studies on masticatory asymmetry in other clinical contexts. Khoury-Ribas et al. [29] found that implant-supported fixed partial prostheses (ISFPPs) led to a significant shift toward bilateral chewing, reducing the asymmetry index over 3 months. Although our study focused on endodontic pain rather than edentulism, both studies highlight the role of occlusal rehabilitation—whether through RCT or prosthetic intervention—in restoring neuromuscular balance and preventing long-term functional disturbances.

A major strength of this study is the use of USG as a non-invasive, reproducible imaging technique for assessing muscle thickness. USG has been validated for evaluating masticatory muscles and provides an accessible alternative to more complex imaging techniques such as MRI or CT [30]. Additionally, our study followed a standardised measurement protocol with high intra-observer reliability (ICC = 0.92), enhancing the validity of our findings.

Several limitations should be considered when interpreting the findings of this study. The lack of a separate healthy control group limited the ability to draw direct comparisons with normative muscle thickness data. Although the self-controlled design minimised inter-individual variability and enabled robust within-subject comparisons, potential compensatory hypertrophy on the asymptomatic side due to masticatory laterality may have influenced baseline asymmetry levels. Nonetheless, the thickness measurements from the asymptomatic side aligned with normative values reported in the literature, which mitigates this concern to some extent [13]. The relatively small sample size ($n = 20$) may limit the generalisability of the findings. However, the study design was guided by an a priori power analysis based on pilot data to ensure sufficient statistical power. In addition, the use of a standardised imaging protocol, high internal consistency and methodological rigor strengthens the reliability of the results. Nonetheless, future studies involving larger and more diverse populations are recommended to validate and extend these findings. Another limitation is the exclusive focus on morphological parameters. EMG data, which could provide insights into neuromuscular activity and functional adaptation, were not included. As noted by Ginszt and Zieliński (2021), EMG is an effective tool for assessing masticatory muscle function [11]. Future studies incorporating both USG and EMG are needed to evaluate structural and functional changes together. Although the 3-month follow-up revealed significant improvements in muscle asymmetry, the long-term stability of these changes remains unclear. While previous studies have shown that neuromuscular adaptation can occur within weeks to months after

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occlusal or prosthetic interventions [11, 29], the permanence of these effects may vary depending on occlusal dynamics, parafunctional habits and individual muscle activity. Longer-term studies are needed to assess the durability of these post-treatment adaptations. Participants' awareness of being part of a study may have influenced their behaviour, possibly leading to a quicker return to bilateral chewing after treatment. Although participant blinding was neither ethically appropriate nor practically feasible due to the clinical nature of the intervention—namely, root canal treatment for symptomatic teeth—this behavioural effect has been acknowledged among the study's limitations. To better isolate effects directly attributable to the intervention, future studies are encouraged to incorporate structured behavioural monitoring strategies. Finally, although patients with clearly defined parafunctional habits were excluded, undiagnosed or subclinical behaviours (e.g., sleep bruxism and mild clenching) were not systematically assessed and may have acted as hidden confounding variables. Future research should consider the use of validated diagnostic tools, such as sleep bruxism questionnaires or surface EMG, to better account for the influence of parafunction on masticatory muscle adaptation and asymmetry.

5 | Conclusions

This study provides evidence that endodontic pain-induced masticatory laterality leads to muscle asymmetry, particularly in the masseter muscle, and that root canal treatment helps restore muscular balance. The findings emphasise the importance of timely endodontic intervention not only for pain management but also for preventing neuromuscular adaptations that could contribute to long-term dysfunction. Future research incorporating electromyographic analysis, longer follow-up periods and larger sample sizes will further elucidate the relationship between endodontic pain, chewing behaviour and masticatory muscle function.

Author Contributions

Kübra Gürler: conceptualisation, data curation, formal analysis, investigation, methodology, writing original draft, supervision, writing review and editing. **İmran Güner Akgül:** investigation, methodology, writing original draft. **Hazal Duyan Yüksel:** investigation, methodology, formal analysis, visualisation, writing review and editing. **Selen Nihal Sisli:** investigation, methodology, writing original draft, supervision, writing review and editing.

Acknowledgements

The authors have nothing to report.

Disclosure

Authors declare any financial support or relationships that may pose a conflict of interest by disclosing any financial arrangements we have with a company whose product figures prominently in the submitted manuscript or with a company making a competing product, or any conflict relating to technology or methodology. The authors also claim the absence of any interest to disclose.

Ethics Statement

Ethical approval was obtained from the Cukurova University Research Ethics Committee (meeting no: 144, decision no: 32, date: May 10, 2024).

Consent

Informed consent was obtained from all individual participants included in the study.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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