

Selective Root Canal Treatment Versus Conventional Root Canal Treatment: A Biomechanical Comparison in a Three-Dimensional Finite Element Study of a Two-Rooted Premolar

Albaraa Alkady

elbaraa.elkady@miuegypt.edu.eg

Misr International University

Karim mahmoud

Misr International University

Nermeen Sami Afifi

Ain Shams University

Abeer Hashem Mahran

Ain Shams University

Article

Keywords: finite element analysis, selective root canal treatment, vital pulp therapy, canal preparation, maxillary first premolar, dentin stress

Posted Date: October 27th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-11231014/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Objectives

To compare dentin stress after selective (SRCT) versus conventional (NSRCT) root canal treatment in a two-rooted maxillary first premolar.

Materials and methods

A five-body finite element model with a conservative, unrestored access cavity common to both treated groups was compared with the intact tooth using quadratic tetrahedra and bonded interfaces. In NSRCT both canals received an ISO 35/.04 preparation and gutta-percha; in SRCT only the palatal canal was prepared, and the buccal canal retained native pulp beneath a 2-mm MTA cap. Loads of 100 N, vertical and 45°, were applied identically in all groups. Von Mises stress (top-decile mean) was probed at the crown, cervical and mid-root dentin, and in dentin adjacent to each canal wall; a 1.64-fold finer mesh tested sensitivity.

Results

SRCT and NSRCT gave the same crown, cervical and mid-root stress (0.2% or less, both meshes). Preparation raised stress adjacent to the prepared palatal canal by about 8–19% versus the intact tooth, identically in both groups; the unprepared buccal canal in SRCT showed no comparable rise. The access cavity raised crown stress by 13–34%, similarly in both groups.

Conclusions

SRCT did not increase dentin stress relative to NSRCT. Canal preparation, not the treatment strategy, raised stress next to a prepared wall; sparing the buccal canal in SRCT spared its wall from this effect.

Clinical relevance:

The mechanical case against selective treatment is not supported here, and its conservatism showed up exactly where expected – sparing the untouched canal wall – rather than at the whole-tooth level. Minimizing canal enlargement, not the choice between selective and conventional treatment, may matter most for root dentin.

Introduction

Interest in preserving vital pulp tissue has grown with hydraulic calcium silicate cements [1] and with diagnostic frameworks that grade pulpitis by severity and guide conservative management [2]. In multirooted teeth this raises the possibility of selective root canal treatment (SRCT), in which vital pulp therapy is applied to one root while the other is treated conventionally; a clinical study has combined the two approaches in mandibular molars [3]. Whether such a strategy alters the mechanical behavior of the tooth, compared with treating all canals conventionally (NSRCT), has not been quantified in a model that also accounts for the access cavity and for canal preparation, both of which independently affect tooth stiffness.

Endodontically treated teeth are more susceptible to fracture, and laboratory work attributes this mainly to lost coronal and radicular structure rather than to the canal filling material itself: endodontic procedures were reported to reduce cuspal stiffness only modestly overall, with the access opening as the main contributor, and progressive canal enlargement adding a further, smaller reduction [4]. Conservative access cavity designs have therefore been proposed to limit this loss [5]. A fair comparison of SRCT with NSRCT needs to hold the access cavity constant between groups and represent canal preparation explicitly, so that any difference between strategies reflects the treatment decision rather than incidental differences in how much tooth structure was removed.

The maxillary first premolar is a suitable model because most have two roots with separate canals [6, 7], which allows one root to be treated conventionally while the other retains vital pulp. We compared dentin stress among an intact tooth, NSRCT and SRCT, using a conservative access cavity common to both treated groups and an ISO 35/.04 canal preparation applied wherever a canal was conventionally treated, under vertical and oblique loading, and examined how sensitive the findings were to mesh density.

Materials and methods

Model geometry

A five-body solid model of a two-rooted maxillary first premolar was built (enamel, dentin, pulp chamber, buccal canal and palatal canal), with crown and root proportions guided by standard anatomical references [8] and canal taper following typical micro-CT-based descriptions of premolar canal morphology [7]; the origin was placed at the cemento-enamel junction (CEJ), with apical distances negative. Bodies were meshed as conforming, bonded volumes so that neighboring materials share nodes. The intact model comprised 484.9 mm³ (enamel 142.1, dentin 315.5, chamber 22.7, and 2.3 mm³ for each canal).

Access cavity

A conservative ovoid access cavity, 2.6 mm buccolingually and 1.8 mm mesiodistally at the occlusal level and converging by 6° toward the floor, was removed from enamel and dentin through the central fossa into the chamber, removing 10.7 mm³ (2.2% of the tooth volume). The same cavity was used in

NSRCT and SRCT and was left unrestored, so that its own mechanical contribution could be measured and then held constant while the canal treatment strategy was varied. A larger, conventional outline was not used because it would have approached the buccal cusp tip in this crown.

Canal preparation and groups

Three groups were compared. In the intact group, the chamber and both canals contained native pulp and no cavity was present. In NSRCT, both canals were enlarged to an ISO 35/.04 preparation (0.35 mm diameter at the working length, 0.04 mm/mm taper, working length 0.5 mm short of the apical foramen) and filled with gutta-percha; the chamber and access cavity were empty. In SRCT, only the palatal canal received the same 35/.04 preparation and gutta-percha fill; the buccal canal was left at its natural, unprepared diameter, with native pulp beneath a 2-mm mineral trioxide aggregate (MTA) cap at the orifice, and the chamber and cavity were empty. Prepared canal geometry was constructed as the union of the natural canal and the instrument envelope at each level, so that the preparation strictly contains the original canal; this enlarged the canal volume from 2.3 mm³ (natural) to about 3.2 mm³ (prepared, either canal), removing about 0.9 mm³ of additional dentin per prepared canal (Fig. 3).

Materials

All materials were linear elastic and isotropic: enamel $E = 84,100$ MPa ($\nu = 0.30$) and dentin $E = 18,600$ MPa ($\nu = 0.31$) [9]; native pulp $E = 2$ MPa ($\nu = 0.45$), assumed, consistent with its near-fluid mechanical behavior; gutta-percha $E = 69$ MPa ($\nu = 0.45$), from direct measurement reported in a materials patent [10]; and MTA $E = 11,000$ MPa ($\nu = 0.33$), a nanoindentation-derived value [11]. Because reported MTA moduli vary by more than an order of magnitude depending on measurement method, a sensitivity analysis repeated the SRCT solution with a bulk-testing-derived modulus, $E = 387$ MPa [11], for comparison. Empty spaces (chamber and access cavity in the treated groups) were represented by a very soft material ($E = 1$ MPa) to keep the mesh connected; they carry no meaningful load.

Solver and validation

Analyses used an in-house finite element solver written in Python with 10-node quadratic tetrahedra and a multigrid-preconditioned conjugate gradient solution to a relative residual of 10^{-6} . The solver was checked against analytical problems: a patch test (maximum relative stress error 3×10^{-14}), a thick-walled cylinder (inner hoop stress error 0.05%), a bimaterial bonded block (exact), and a cantilever beam, for which the quadratic elements were within about 1% of beam theory at every mesh size tested, whereas linear tetrahedra underestimated tip deflection by 13–46%.

Boundary conditions and loading

The periodontal ligament was represented as an elastic foundation over the exterior root surface (203 mm²), with stiffness per unit area $E/t = 68.9 \text{ MPa} / 0.20 \text{ mm} = 344.5 \text{ N/mm}^3$ acting in all directions, and the apical tips (more than 13 mm apical to the CEJ) were fixed. Two static loads of 100 N were applied identically in all three groups, to the same set of crown-surface faces oriented toward the occlusal surface (faces within the access-cavity footprint were excluded in every group, including the intact tooth, so the loaded area — 14.4 mm² vertical, 10.6 mm² oblique — did not differ between groups): a vertical load on faces within 1.5 mm of the crown top, and a load directed at 45° (lingually and apically) on faces within 2 mm of the crown top and between 0.2 and 1.8 mm buccal of the axis, on the buccal cusp incline (Fig. 1).

Outcomes and mesh sensitivity

Stress in each element was the von Mises stress averaged over its integration points. For each probe region, the outcome was the mean of the top decile of element values, except for the canal-wall probes below, where the region mean is reported because the top-decile value was not mesh-converged (see Results). Probe regions were dentin from 2.5 to 1.1 mm apical to the CEJ on the buccal and on the palatal side, restricted to elements bordering the enamel-dentin junction or the furcation region were excluded by this range (cervical); buccal dentin 8 to 11 mm apical to the CEJ (mid-root); enamel plus dentin coronal to 0.3 mm above the CEJ (crown); and, separately, dentin elements within 0.25 mm of a canal wall within the cervical range, analyzed on the buccal and palatal sides (canal-wall probes). Two mesh densities were used: a base mesh (about 68,000 elements for each group) and a 1.64-fold finer mesh, generated independently rather than by uniform refinement. The model is deterministic, so no inferential statistics were applied.

Results

SRCT and NSRCT produced the same crown, cervical and mid-root stress: they differed by 0.2% or less in every such probe, on both the base and the finer mesh (Table 1). This held regardless of loading direction.

Relative to the intact tooth, the access cavity raised crown stress in both treated groups by the same amount: 13.1% under vertical loading (falling to 9.2% on the finer mesh) and 34.0% under oblique loading (27.2% fine mesh); this effect was not converged under oblique loading and should be read as directional rather than precise. Cervical and mid-root dentin stress, away from the canal walls, changed little with treatment (Table 1, Fig. 2).

Canal preparation had a localized effect not captured by the cervical and mid-root probes above. In the dentin immediately adjacent to the palatal canal wall — prepared to 35/.04 in both NSRCT and SRCT — mean stress rose by 7.6% (vertical) and 31.1% (oblique) relative to the intact tooth, essentially identically in the two groups (7.7% and 31.4% for SRCT) (Fig. 4, Table 2). This mean value was stable on the finer

mesh (7.5% and 19.4%), although the top-decile value at this probe was not (base-mesh oblique + 10.3%, fine-mesh + 0.6%), so only the region-mean canal-wall values should be treated as reliable.

The unprepared buccal canal in SRCT showed a smaller and mesh-sensitive change in its adjacent wall (-5.6% to -6.2% across loadings and meshes), compared with a similarly small change when that canal was instead prepared, as in NSRCT (-7.9% to -12.3%). With the natural (unprepared) buccal canal and the nanoindentation MTA modulus (11,000 MPa), the adjacent wall showed a modest reduction relative to the intact tooth (-5.9% vertical, -6.2% oblique); this reduction was not reproduced with a bulk-testing MTA modulus (387 MPa: -0.0% and - 0.5%), indicating that this particular reduction depends on which MTA modulus is assumed and should not be read as a robust finding.

Table 1
Von Mises stress (MPa; mean of the top decile of element values) on the base mesh, with percent change relative to the intact tooth in parentheses. NSRCT and SRCT both include the access cavity and, where applicable, a 35/.04 canal preparation.

Region	Load	Intact	NSRCT	SRCT
Cervical, buccal	Vertical	7.53	7.53 (- 0.0%)	7.51 (- 0.2%)
Cervical, buccal	Oblique	14.11	14.13 (+ 0.1%)	14.11 (+ 0.0%)
Cervical, palatal	Vertical	3.65	3.66 (+ 0.1%)	3.65 (- 0.1%)
Cervical, palatal	Oblique	19.69	19.67 (- 0.1%)	19.66 (- 0.1%)
Mid-root, buccal	Vertical	3.75	3.75 (- 0.0%)	3.75 (+ 0.0%)
Mid-root, buccal	Oblique	5.40	5.39 (- 0.0%)	5.40 (+ 0.0%)
Crown	Vertical	9.10	10.29 (+ 13.1%)	10.29 (+ 13.1%)
Crown	Oblique	21.19	28.40 (+ 34.0%)	28.40 (+ 34.1%)

Table 2
Mean von Mises stress (MPa) in dentin within 0.25 mm of each canal wall, cervical band, base mesh, with percent change relative to the intact tooth. The palatal canal was prepared (35/.04) in both treated groups; the buccal canal was prepared in NSRCT and left natural (with an MTA cap) in SRCT.

Wall	Load	Intact	NSRCT	SRCT
Palatal (prepared, both groups)	Vertical	1.31	1.41 (+ 7.6%)	1.41 (+ 7.7%)
Palatal (prepared, both groups)	Oblique	5.20	6.82 (+ 31.1%)	6.84 (+ 31.4%)
Buccal (prepared in NSRCT only)	Vertical	3.52	3.24 (- 7.9%)	3.32 (- 5.6%)
Buccal (prepared in NSRCT only)	Oblique	3.55	3.11 (- 12.3%)	3.33 (- 6.2%)

Discussion

The central finding is that SRCT and NSRCT produced the same crown, cervical and mid-root dentin stress (0.2% or less throughout). This held with the access cavity present in both groups and with canal preparation explicitly modeled, which addresses the two features — loss of coronal structure and loss of radicular structure — identified by laboratory work as the principal determinants of reduced tooth stiffness after endodontic treatment [4]. In this model, at the scale of the crown and of dentin away from the canal walls, the choice between selective and conventional treatment did not add to that mechanical cost.

Canal preparation did have a measurable, localized effect: dentin immediately adjacent to a prepared canal wall carried more stress than the same region in an intact tooth, by an amount that was essentially the same whether the canal belonged to an NSRCT or an SRCT tooth. This is consistent with a straightforward mechanism — removing dentin next to the canal wall thins the load path locally — and it implies that the mechanical cost attributed here to “treatment” is more precisely a cost of instrumentation. In SRCT, the buccal canal is not instrumented, and its adjacent wall did not show this rise; whatever difference SRCT makes to canal-wall stress follows from sparing that canal from preparation, not from a separate biomechanical property of vital pulp therapy itself. An apparent stress reduction at the unprepared wall with a stiff MTA cap did not persist when a lower, bulk-measured MTA modulus was used, so that particular finding should be treated as sensitive to material assumptions rather than as a robust benefit of SRCT.

The access cavity, common to both treated groups, was associated with higher crown stress than in the intact tooth, most under oblique loading; this size estimate was not mesh-converged and should be read as directional. This finding does not distinguish SRCT from NSRCT, since both shared the same cavity, but it does mean that overall comparisons of a treated tooth with an intact one — as opposed to comparisons between treatment strategies — should account for the access cavity and not only for the canal filling material, a distinction not always made explicit in prior finite element work on root canal treatment.

For clinicians, these findings suggest that the decision between SRCT and conventional treatment need not be driven by a difference in dentin stress, since none was found once both procedures were represented with a comparable access cavity and, where instrumented, a comparable canal preparation. If canal-wall stress is a concern, minimizing enlargement — consistent with minimally invasive endodontic principles more broadly [5] — may matter more than the choice between selective and conventional strategies. These are computational findings on one idealized tooth and do not replace clinical evidence.

Several limitations apply. The geometry represents a single premolar with one access outline and one preparation size; other anatomies, cavity designs or preparation tapers were not tested. The cavity was left unrestored, so the results describe the period before restoration; restoring the tooth would be expected to reduce the crown-stress effect of the cavity, but this was not modeled. Canal-wall probes are new to this analysis and were more mesh-sensitive than the cervical, mid-root and crown probes; we

report only the region-mean value for this reason and note that the corresponding top-decile value was not converged. Interfaces were perfectly bonded, materials were linear, isotropic and homogeneous, and the periodontal ligament was an elastic foundation. Loading was static, and fatigue and the behavior of material interfaces under repeated loading were not examined. The reduction in buccal-wall stress attributed to the MTA cap was sensitive to the assumed MTA modulus and should not be relied upon. Von Mises stress is a ductile-material measure, whereas dentin is brittle, so values should be read comparatively rather than against a fracture threshold.

Conclusions

In this finite element model, selective and conventional root canal treatment produced the same dentin stress at the crown, cervical and mid-root regions (0.2% or less). Canal preparation, rather than the treatment strategy, raised stress in the dentin adjacent to a prepared canal wall; because SRCT leaves one canal unprepared, it spared that wall from this effect, while the access cavity common to both treated groups raised crown stress in both to the same extent. Selecting SRCT did not add mechanical cost relative to conventional treatment in this model. Clinical studies are needed to confirm these computational findings.

Declarations

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

Conflict of interest: The authors declare that they have no competing interests.

Ethics approval and consent to participate: Not applicable. This is a computational study; no human or animal subjects, tissues or data were involved.

Data availability: Model geometry files, solver scripts and result tables are available from the corresponding author on reasonable request.

The authors received no specific funding for this work.

Author Contribution

Albaraa Alkady. conceived and designed the study, developed the computational model, performed the analysis, prepared the figures and tables, and wrote the main manuscript text. Abeer Hashem Mahran . contributed to conceptualization and methodology, supervised the work, and validated the results. karim mahmoud. contributed to data investigation. Nermeen sami. contributed scientific review and consultation. All authors reviewed and approved the final manuscript.

Acknowledgments:

None.

References

1. Parirokh, M., Torabinejad, M. & Dummer, P. M. H. Mineral trioxide aggregate and other bioactive endodontic cements: an updated overview – part I: vital pulp therapy. *Int. Endod J.* **51**, 177–205 (2018).
2. Wolters, W. J. et al. Minimally invasive endodontics: a new diagnostic system for assessing pulpitis and subsequent treatment needs. *Int. Endod J.* **50**, 825–829 (2017).
3. Koli, B., Chawla, A., Logani, A., Kumar, V. & Sharma, S. Combination of nonsurgical endodontic and vital pulp therapy for management of mature permanent mandibular molar teeth with symptomatic irreversible pulpitis and apical periodontitis. *J. Endod.* **47**, 374–381 (2021).
4. Reeh, E. S., Messer, H. H. & Douglas, W. H. Reduction in tooth stiffness as a result of endodontic and restorative procedures. *J. Endod.* **15**, 512–516 (1989).
5. Krishan, R. et al. Impacts of conservative endodontic cavity on root canal instrumentation efficacy and resistance to fracture assessed in incisors, premolars, and molars. *J. Endod.* **40**, 1160–1166 (2014).
6. Olczak, K., Pawlicka, H. & Szymański, W. Root form and canal anatomy of maxillary first premolars: a cone-beam computed tomography study. *Odontology* **110**, 365–375 (2022).
7. Vertucci, F. J. Root canal anatomy of the human permanent teeth. *Oral Surg. Oral Med. Oral Pathol.* **58**, 589–599 (1984).
8. Nelson, S. J. *Wheeler's dental anatomy, physiology, and occlusion* 10th edn (Elsevier, 2015).
9. Rees, J. S. & Jacobsen, P. H. The elastic moduli of enamel and dentine. *Clin. Mater.* **14**, 35–39 (1993).
10. Cone material in endodontic treatment. *US Patent* 8088838 (2012).
11. Žižka, R. et al. In vitro mechanical properties of mineral trioxide aggregate in moist and dry intracanal environments. *Iran. Endod J.* **13**, 20–24 (2018).

Figures

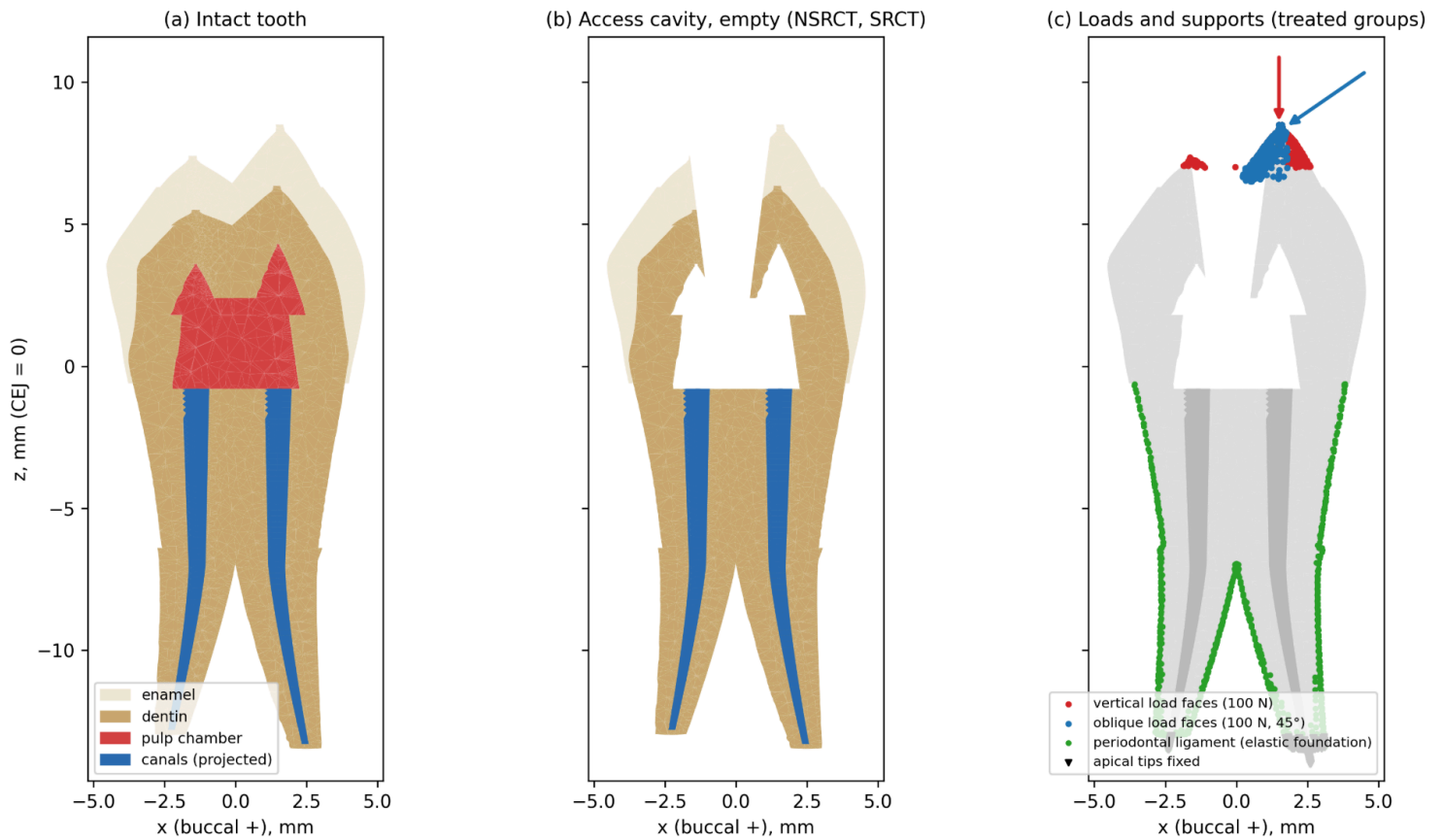


Figure 1

Sagittal section through the chamber centre: intact tooth (a), the unrestored conservative access cavity common to both treated groups (b), and the loaded faces and boundary conditions (c). The loaded area (red, vertical; blue, oblique) excludes the access-cavity footprint in every group, including the intact tooth

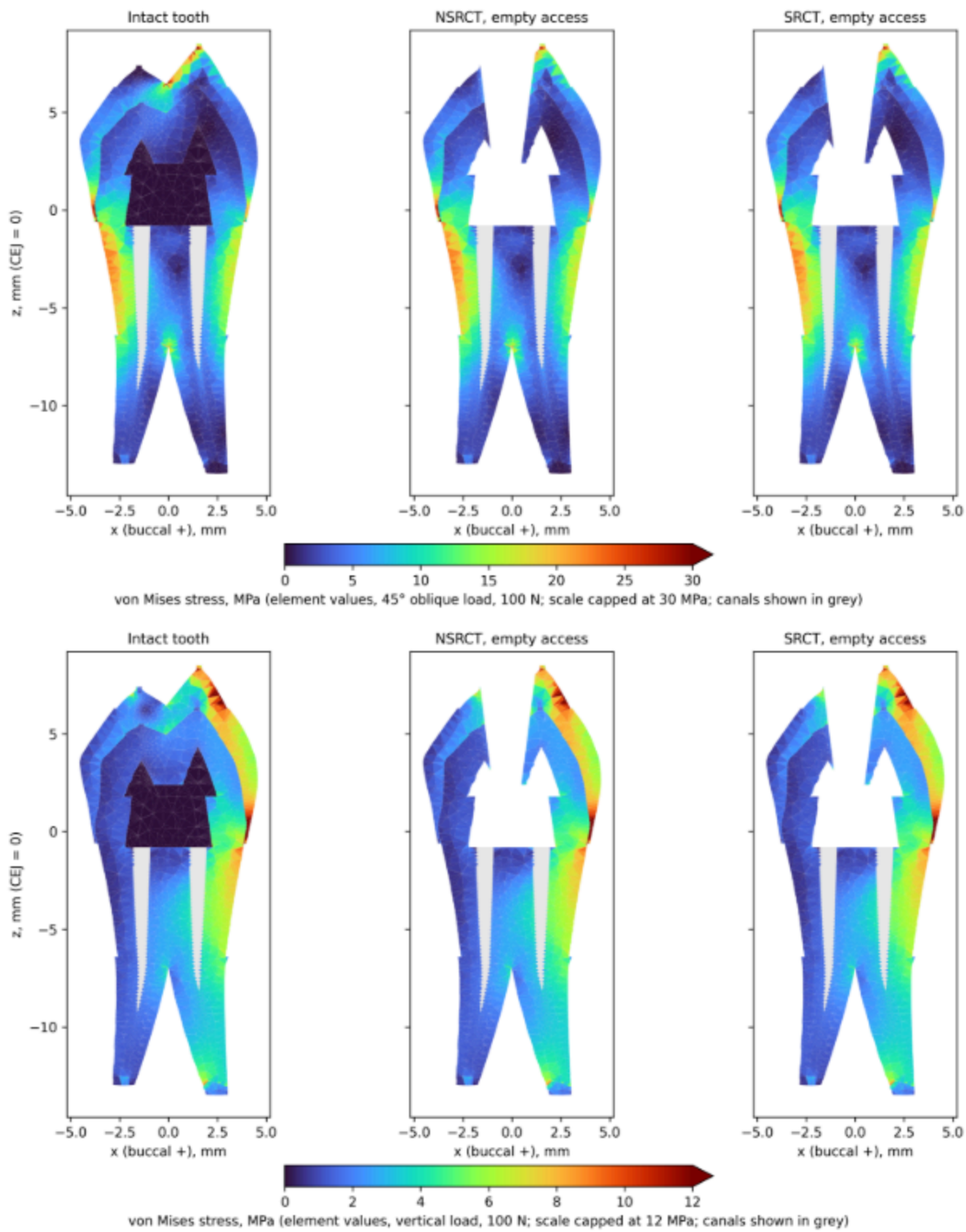


Figure 2

Von Mises stress (element values) in the sagittal section for the intact tooth, NSRCT and SRCT, under the 100-N load at 45° (top row, scale capped at 30 MPa) and under the 100-N vertical load (bottom row, scale capped at 12 MPa). Canals are shown in grey

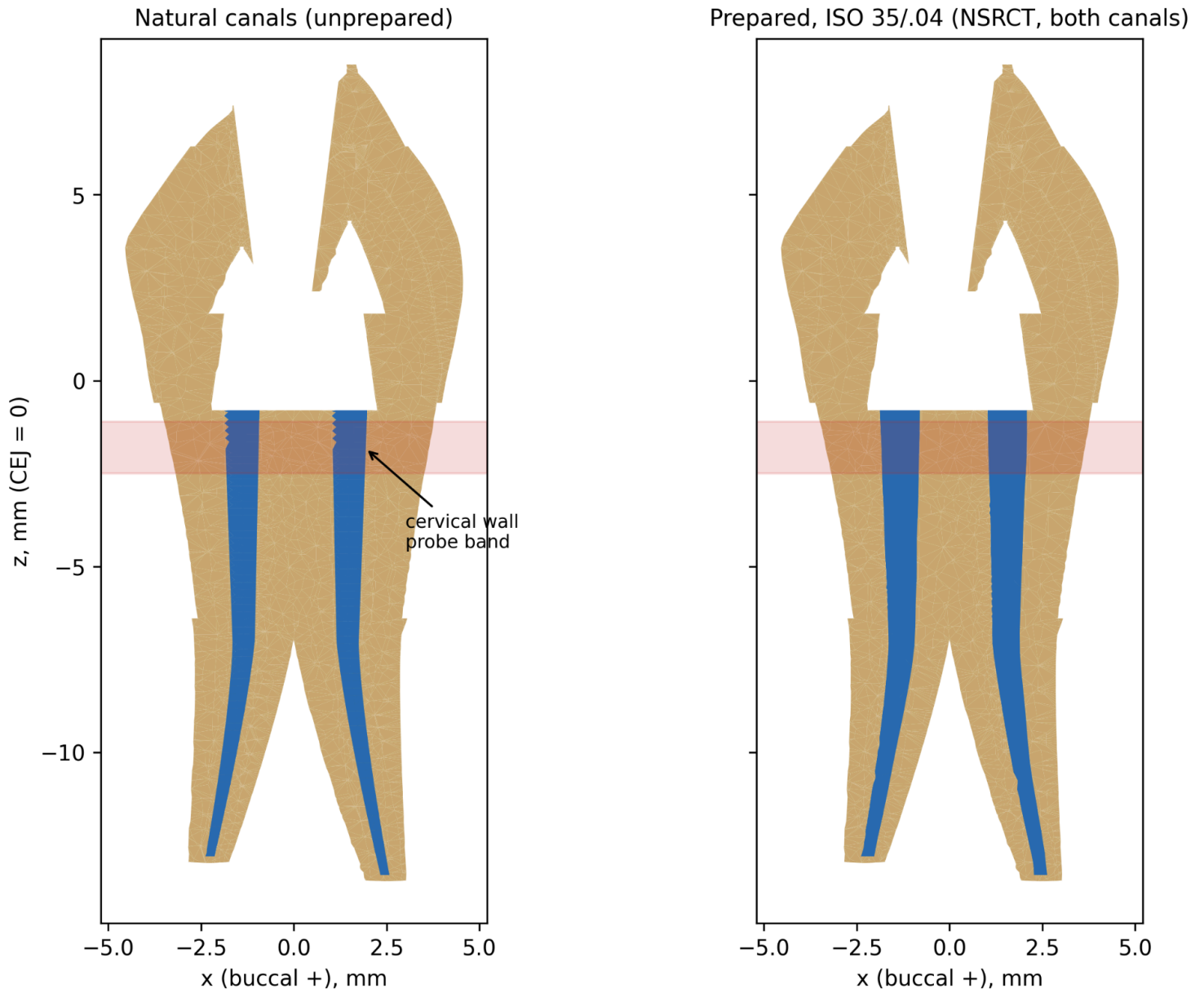


Figure 3

Sagittal comparison of natural (unprepared) canals and canals prepared to ISO 35/.04, shown for the NSRCT geometry; the shaded band marks the cervical canal-wall probe region used in Table 2

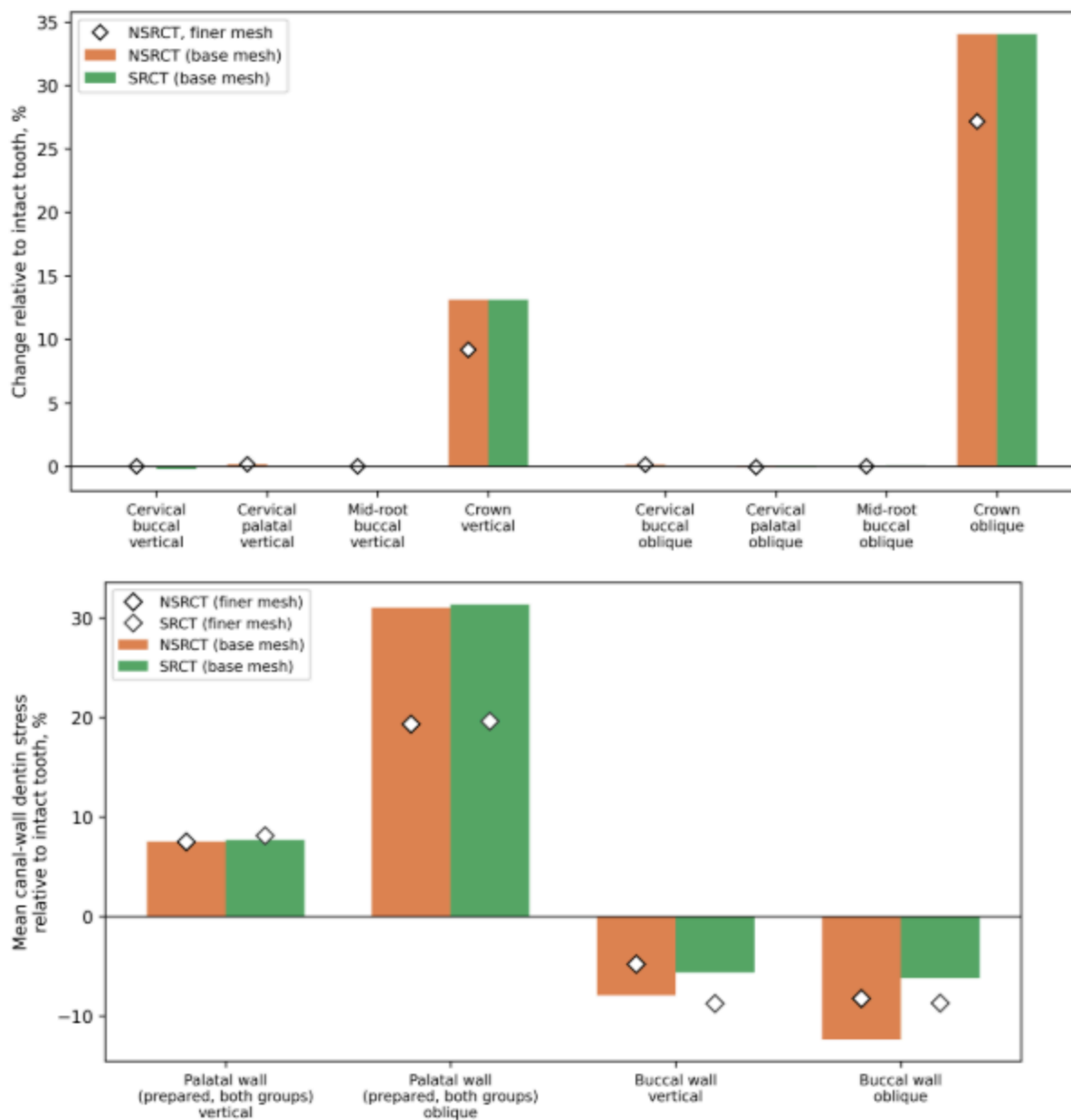


Figure 4

Top: change in crown, cervical and mid-root stress relative to the intact tooth for NSRCT and SRCT, base mesh (bars) and finer mesh (diamonds, NSRCT only). Bottom: mean canal-wall dentin stress relative to the intact tooth, palatal (prepared in both groups) versus buccal (prepared in NSRCT only), base mesh (bars) and finer mesh (diamonds)