Research Article

Effect of A Novel Atraumatic Rubber Dam Clamp on Cementoenamel Junction Surface Roughness: An in Vitro Experimental Study

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Abstract

BACKGROUND: Rubber dam clamps provide essential tooth retention during operative procedures but establish a localized mechanical interface with the cervical tooth surface. Clamp material and geometry may influence surface alteration at the cementoenamel junction (CEJ), although comparative evidence involving atraumatic designs remains limited.

AIM: To compare changes in CEJ surface roughness following application of four rubber dam clamp designs for 30 minutes, 1 hour, and 2 hours.

METHODS: Seventy-two extracted human molars with intact cervical surfaces were randomly allocated to four clamp groups: NMD polymer, smooth stainless steel, serrated stainless steel, and a novel atraumatic polylactic acid (PLA) clamp. Six specimens from each group were evaluated at each application duration. Surface roughness (Ra) was measured using contact profilometry before and immediately after clamp application, with five standardized traces obtained per specimen. The primary outcome was percentage change in Ra. Within-group changes were assessed using paired comparisons, while differences among clamp groups at each duration were evaluated using the Kruskal-Wallis test followed by Dunn-Bonferroni post hoc analysis.

RESULTS: All 72 specimens completed the experimental protocol. The novel PLA clamp demonstrated the lowest mean percentage change in Ra at 30 minutes (2.81 ± 2.09%), 1 hour (2.50 ± 1.82%), and 2 hours (3.91 ± 2.71%). A significant between-group difference was identified at 1 hour ($H = 8.940$, $P = .030$; $\varepsilon^2 = .297$), with the only significant pairwise difference occurring between the serrated stainless-steel and novel PLA groups (adjusted $P = .048$). Between-group differences were not significant at 30 minutes ($H = 6.040$, $P = .110$) or 2 hours ($H = 6.547$, $P = .088$).

CONCLUSION: Clamp design was associated with CEJ surface roughness alteration at the 1-hour application period, whereas no significant between-group differences were detected at 30 minutes or 2 hours. The consistently lower numerical roughness change observed with the novel PLA clamp warrants further investigation using microscopic and mechanical analyses before its surface-protective performance can be established.

KEYWORDS: Sustainable dentistry; Oral health, Rubber dam clamp, Cemento-enamel junction, roughness.

INTRODUCTION

The use of a rubber dam in restorative and endodontic dentistry is a common practice for moisture control, better visibility, retraction of soft tissues, and to prevent aspiration or ingestion of materials. The efficiency of the isolation depends on the stability of the clamp on the cervical surface of the tooth. However, localised mechanical forces at the interface between the clamp and tooth could affect the integrity of the cervical surface.(1–3)

The cementoenamel junction (CEJ) is of particular interest as the enamel–cementum transition is a morphologically complex surface on which clamp forces may be focused.(4) Previous experimental data have shown that poor adaptation of metal clamp edges can cause iatrogenic surface defects, and finite element analysis has demonstrated that tooth stress with stainless-steel clamps is greater than PEEK clamps.(5,6)

The surface roughness measurement provides a quantitative means to detect the subtle change induced by the clamp contact. Kayalidere et al. (2025) showed that rubber dam clamp application can change the CEJ roughness, and the extent and morphology of the change depend on the clamp material and design. Microscopic examination revealed distinct surface changes in polymer, smooth stainless-steel, and serrated stainless-steel clamps in their study at 30 minutes, 1 hour and 2 hours.(7)

However, the effect of an atraumatic clamp geometry on CEJ surface roughness is still inadequately characterised. Therefore, this in vitro study compared the percentage change in CEJ surface roughness (Ra) by

four rubber dam clamp designs at 30 min, 1 hour and 2 hours of application. The null hypothesis was that the clamp design would not influence the percentage change in Ra at any tested duration.

MATERIALS AND METHODS

Study Design and Specimen Preparation

The objective of this in vitro experimental study was to evaluate changes in cementoenamel junction (CEJ) surface roughness after application of four rubber dam clamp designs for three clinically relevant application times. Inclusion criteria: seventy-two human extracted molars with intact cervical surfaces. Teeth were examined for visible caries, restorations, cracks, fractures, wear defects, or developmental abnormalities that could affect the planned measurement area. The remaining periodontal tissue and adherent debris were removed without instrumentation of the cervical surface. The specimens were stored in an aqueous medium until preparation and testing. The storage conditions were maintained consistent throughout the experimental period.

The teeth were embedded one by one in a block of autopolymerizing acrylic resin, leaving the clinical crown exposed, to allow for standardised placement of the clamps and profilometric assessment. The specimens were then divided into 4 clamp groups and 3 application duration groups, 6 specimens in each group-duration combination (4 clamp groups × 3 durations × 6 specimens = 72 teeth).

Sample Size Determination

Sample-size planning was performed according to the method reported in the reference study by Erden Kayalidere et al ,(7) which studied the changes in CEJ surface roughness after the application of rubber dam clamps. The study considered a minimum difference between measurements of 0.1 µm to be clinically relevant with an estimated effect size of d = 2.20. The calculation showed that a minimum of 54 specimens (6 specimens per experimental subgroup) were necessary to obtain 80% power with a two-sided significance level of $\alpha = 0.05$. For the current four-clamp, three-duration design, the sample was increased to 72 specimens to provide six specimens for each of the 12 designated experimental cells. Therefore the final allocation was equally distributed between clamp type and application duration.

Experimental Groups and Clamp Characteristics

Specimens were randomly assigned to one of four clamp groups:

Group 1: commercially available polymer rubber dam clamp (NMD Dental Navi Mumbai, India)

Group 2: rubber dam clamp with smooth surface stainless steel (Black Line RDCM7X, Hu-Friedy Group, Chicago, IL, USA).

Group 3: serrated stainless steel rubber dam clamp (Fiesta Colour Coded, COLTENE, Altstätten, Switzerland).

Group 4: new atraumatic rubber dam clamp made from polylactic acid (PLA) according to the design of the investigators.

The nonmetallic comparator was a commercially available polymer clamp. The two stainless-steel clamps represented conventional metallic designs with differing surface configuration.

Randomization and Allocation of Specimens

After assessment of eligibility and specimen preparation, the 72 teeth were randomly divided into the four clamp groups by computer-generated randomisation sequence. Randomisation was done before application of the clamp, with equal allocation to each group within each application duration cohort. The allocation sequence was generated independently from the operator, who was responsible for the specimen preparation and clamp application, to minimise selection bias. An identification number was assigned to each specimen, which was stored for the duration of the profilometric assessment.

Standardization of the CEJ Measurement Region

Before the application of the clamp, the standard CEJ region of each specimen was evaluated with a contact surface profilometer (Surftest 410, Mitutoyo, Kawasaki, Japan) following the profilometric protocol described in the reference methodology [5]. Five independent traces were taken from each sample. Each trace was taken over a 1.25-mm transverse distance in the mesiodistal direction with a cut-off value of 0.25 mm. The arithmetic

mean surface roughness (Ra, µm) was recorded for each trace. The five readings were averaged to provide a specimen level baseline Ra value.
The profilometer was kept under the same measurement conditions for all specimens. The measurement direction, trace length, cut-off value and acquisition procedure were not changed for the respective post-application assessment.

Baseline Surface Roughness Assessment
Before clamp application, the standardized CEJ region of every specimen was evaluated using a contact surface profilometer (Surftest 410, Mitutoyo, Kawasaki, Japan), following the profilometric protocol described in the reference methodology [5]. Five independent traces were obtained from each specimen. Each trace was recorded over a 1.25-mm transverse distance in the mesiodistal direction, using a 0.25-mm cut-off value. The arithmetic mean surface roughness (Ra, µm) was recorded for each trace, and the five readings were averaged to obtain a specimen-level baseline Ra value.(7)
The profilometer was maintained under the same measurement conditions for all specimens. The measurement direction, trace length, cut-off value, and acquisition procedure were kept unchanged for the corresponding post-application assessment.

Clamp Application Protocol
The allocated clamp was placed on the designated CEJ area of each specimen using a standardised approach. One clamp was used per tooth to prevent repeated use of the same clamp on multiple specimens, and to minimise possible variation associated with repeated use or mechanical deformation.
Specimens in each clamp group were further subdivided into three application-duration groups (30 minutes, 1 hour, and 2 hours) (n = 6 for each clamp-duration combination). Under standardised experimental conditions, the clamp was in contact with the designated CEJ region for the entire assigned period. The clamp was then carefully removed after the prescribed time, with no contact or instrumentation of the measurement region.(7)
All specimens were clamped and unclamped by a single operator. This was to reduce variation due to differences in positioning technique.

Post-Application Surface Roughness Assessment
The same predetermined CEJ area was measured again immediately after clamp removal by the same profilometric method used for the baseline measurement. For each specimen five traces were obtained with a 1.25-mm measurement length and 0.25-mm cut-off. The final specimen level Ra value was the average of these five readings.(7)
The primary quantitative measure of surface alteration was the percent change in Ra, calculated as:
% change Ra = [(Ra final - Ra baseline)/Ra baseline] x 100%
Positive percentages indicated an increase in surface roughness following the clamp application and negative percentages indicated a decrease in surface roughness compared to the baseline measurement.

Statistical Analysis
The individual tooth was considered the experimental unit. Data were assessed for normality using the Shapiro-Wilk test. Baseline and final Ra values were compared within each subgroup using the paired-samples test. Percentage change in Ra was compared among the four clamp groups at each application duration using the Kruskal-Wallis test, followed by Dunn's test with Bonferroni adjustment for significant omnibus comparisons. Descriptive data were presented as mean ± standard deviation. All tests were two-sided, with $P < 0.05$ considered statistically significant. Analyses were performed using IBM SPSS Statistics, version 26.0 (IBM Corp., Armonk, NY, USA).

RESULTS

Specimen distribution and baseline comparability

All 72 specimens were included in the analysis, without exclusions or missing measurements. Each application-duration cohort comprised 24 specimens, with six teeth assigned to each clamp group. Baseline Ra values did not differ significantly among the four clamp groups at 30 minutes ($F = 1.121$, $P = 0.364$), 1 hour ($F = 0.910$, $P = 0.454$), or 2 hours ($F = 1.582$, $P = 0.225$). The corresponding effect sizes were $\eta^2 = 0.144$, 0.120, and 0.192, respectively. Final Ra values likewise showed no significant between-group differences at 30 minutes ($F = 0.933$, $P = 0.443$), 1 hour ($F = 0.521$, $P = 0.673$), or 2 hours ($F = 0.904$, $P = 0.457$), with η^2 values of 0.123, 0.072, and 0.119, respectively. [Table 1; Table 2]

Within-group changes in surface roughness

At 30 minutes, Ra increased from baseline in all four groups. The change reached statistical significance in the serrated stainless-steel group ($P = 0.008$) and the novel PLA group ($P = 0.039$), whereas the changes in the NMD ($P = 0.146$) and smooth stainless-steel ($P = 0.079$) groups were not statistically significant. The corresponding percentage changes were 5.98 ± 11.83% for NMD, 16.12 ± 17.83% for smooth stainless steel, 14.45 ± 5.28% for serrated stainless steel, and 2.81 ± 2.09% for novel PLA. [Table 1]

After 1 hour, significant within-group increases in Ra were observed for NMD ($P = 0.025$), serrated stainless steel ($P = 0.034$), and novel PLA ($P = 0.035$). The smooth stainless-steel group did not show a statistically significant change ($P = 0.050$). Percentage changes ranged from 2.50 ± 1.82% in the novel PLA group to 19.13 ± 13.30% in the serrated stainless-steel group. [Table 1]

At 2 hours, the NMD and novel PLA groups demonstrated statistically significant increases in Ra ($P = 0.032$ and $P = 0.028$, respectively). No statistically significant within-group change was observed for either the smooth stainless-steel ($P = 0.058$) or serrated stainless-steel ($P = 0.053$) groups. The percentage changes were 6.83 ± 4.96%, 18.53 ± 17.04%, 21.92 ± 15.51%, and 3.91 ± 2.71% for NMD, smooth stainless steel, serrated stainless steel, and novel PLA, respectively. [Table 1]

Between-group comparison of percentage change in Ra

At 30 minutes, the percentage change in Ra did not differ significantly among the four clamp groups ($H = 6.040$, $P = 0.110$; $\varepsilon^2 = 0.152$). At 1 hour, a significant between-group difference was detected ($H = 8.940$, $P = 0.030$; $\varepsilon^2 = 0.297$). Dunn-Bonferroni post hoc analysis identified a significant difference only between the serrated stainless-steel and novel PLA groups (adjusted $P = 0.048$). All other pairwise comparisons were nonsignificant after adjustment. At 2 hours, the between-group comparison was not statistically significant ($H = 6.547$, $P = 0.088$; $\varepsilon^2 = 0.177$). [Table 3; Table 4]

The mean percentage change in Ra was lowest for the novel PLA clamp at each application duration (2.81%, 2.50%, and 3.91% at 30 minutes, 1 hour, and 2 hours, respectively). The highest numerical percentage change was observed with the smooth stainless-steel clamp at 30 minutes (16.12%) and with the serrated stainless-steel clamp at 1 hour (19.13%) and 2 hours (21.92%). However, statistically significant between-group differences were demonstrated only at 1 hour, with the post hoc difference confined to the serrated stainless-steel and novel PLA groups. [Table 1; Table 3; Table 4]

Table 1. Surface roughness before and after clamp application according to clamp design and application duration

Application duration	Clamp group	Initial Ra (µm) Mean ± SD	Final Ra (µm) Mean ± SD	Percentage change Mean ± SD	Paired P
30 min	NMD	1.08 ± 0.54	1.20 ± 0.70	5.98 ± 11.83	0.146
30 min	Smooth stainless steel	0.98 ± 0.20	1.17 ± 0.41	16.12 ± 17.83	0.079

30 min	Serrated stainless steel	1.35 ± 0.32	1.56 ± 0.44	14.45 ± 5.28	0.008
30 min	Novel PLA	1.12 ± 0.30	1.16 ± 0.33	2.81 ± 2.09	0.039
1 h	NMD	1.18 ± 0.37	1.24 ± 0.41	4.26 ± 2.40	0.025
1 h	Smooth stainless steel	1.20 ± 0.36	1.43 ± 0.58	16.19 ± 13.53	0.050
1 h	Serrated stainless steel	0.93 ± 0.26	1.14 ± 0.43	19.13 ± 13.30	0.034
1 h	Novel PLA	1.15 ± 0.28	1.18 ± 0.31	2.50 ± 1.82	0.035
2 h	NMD	1.55 ± 0.30	1.67 ± 0.40	6.83 ± 4.96	0.032
2 h	Smooth stainless steel	1.01 ± 0.28	1.24 ± 0.51	18.53 ± 17.04	0.058
2 h	Serrated stainless steel	1.39 ± 0.74	1.79 ± 1.12	21.92 ± 15.51	0.053
2 h	Novel PLA	1.31 ± 0.25	1.37 ± 0.30	3.91 ± 2.71	0.028

Values are mean ± standard deviation. Paired P values represent within-specimen comparisons of initial and final Ra.

Table 2. One-way ANOVA comparison of initial and final surface roughness among clamp groups

Duration	**Measurement**	**F**	**P**	**η^2**
30 min	Initial Ra	1.121	0.364	0.144
30 min	Final Ra	0.933	0.443	0.123

1 h	Initial Ra	0.910	0.454	0.120
1 h	Final Ra	0.521	0.673	0.072
2 h	Initial Ra	1.582	0.225	0.192
2 h	Final Ra	0.904	0.457	0.119

One-way ANOVA; df = 3,20 for each comparison. η^2, eta-squared.

Table 3. Kruskal-Wallis comparison of percentage change in Ra among clamp groups

Duration	Kruskal-Wallis H	df	P	ε^2
30 min	6.040	3	0.110	0.152
1 h	8.940	3	0.030	0.297
2 h	6.547	3	0.088	0.177

ε^2, epsilon-squared effect size.

Table 4. Dunn-Bonferroni post hoc analysis of percentage change in Ra at 1 hour

Pairwise comparison	Z	Bonferroni-adjusted P
NMD vs smooth stainless steel	1.347	1.000
NMD vs serrated stainless steel	1.796	0.435
NMD vs novel PLA	0.857	1.000
Smooth vs serrated stainless steel	0.449	1.000
Smooth stainless steel vs novel PLA	2.205	0.165
Serrated stainless steel vs novel PLA	2.654	0.048

DISCUSSION

The present in vitro study evaluated changes in cementoenamel junction surface roughness following application of four rubber dam clamp designs at 4 time intervals. Although final Ra values did not differ significantly among the clamp groups at any duration, the percentage change in Ra revealed a significant between-group difference after 1 hour, with the novel PLA clamp showing the lowest change and the serrated stainless-steel clamp the highest. Dunn-Bonferroni analysis demonstrated a significant difference specifically between these two groups (adjusted P = 0.048). At 30 minutes and 2 hours, the overall comparisons were not statistically significant. The novel PLA group nevertheless showed the lowest numerical percentage change at all three durations. The prespecified null hypothesis, that clamp design would not influence the percentage change in Ra, was therefore partially rejected, as a significant effect of clamp design was demonstrated at 1 hour but not at 30 minutes or 2 hours. Importantly, the findings do not support a generalized claim that the novel PLA clamp was superior across all application periods.

Extracted molars were selected with intact cervical regions . The same pre-defined region of CEJ was evaluated before and after application of clamp, so that the tooth itself was used as a reference.(8) Five profilometric traces were obtained at both time points using a standardized trace length and cut-off, based on the methodology of Kayalidere et al.(7) The use of three application periods permitted assessment of whether the effect was sustained or became more pronounced with increasing contact time, while inclusion of both smooth and serrated stainless-steel clamps allowed the influence of clamp surface configuration to be considered separately from material composition. A commercially available polymer clamp provided an established nonmetallic comparator, whereas the novel PLA design represented the experimental intervention. The use of a single clamp per specimen also avoided potential variation arising from repeated mechanical use. These design features were particularly relevant because CEJ morphology, clamp adaptation, contact geometry, and baseline roughness can all influence the magnitude of profilometric change.

First, results can be directly compared with those of Kayalidere et al. (2025) who used a closely related experimental model for their investigation.(7) The study looked at a polymer clamp, a smooth-edged stainless-steel clamp and a serrated stainless-steel clamp at 30 minutes, 1 hour and 2 hours. There was no significant between-group difference in percentage change at 30 minutes or 2 hours, but the polymer clamp had a significantly lower percentage change than the two metal clamps at 1 hour. This temporal pattern is notably similar to the present findings: the overall comparison was nonsignificant at 30 minutes and 2 hours but significant at 1 hour. However, the present study identified the significant pairwise difference specifically between the serrated stainless-steel and novel PLA clamps, rather than demonstrating a significant difference between the commercial polymer clamp and both stainless-steel designs. This difference may be due to differences in clamp geometry, polymer composition, contact configuration, specimen characteristics and the inclusion of a newly designed PLA clamp in the present investigation.

The within-specimen results also diverged somewhat from Kayalidere et al. (2025).(7) In the study only the serrated metal clamp showed significant increases in roughness after 30 minutes, but all three clamp groups showed significant increases after 1 and 2 hours. In the present study, statistically significant within-group increases were observed in selected groups at each duration, but these did not translate consistently into significant between-group differences. This distinction is important because a significant pre–post change within a clamp group does not establish that the magnitude of change differs from that produced by another clamp. The discrepancy may partly reflect the smaller subgroup size in the present four-group design (n = 6 per cell), differences in baseline Ra values, and the introduction of a fourth clamp design. Moreover, Kayalidere et al. used a polymer SoftClamp, whereas the present study used the NMD polymer clamp and a PLA-based experimental design. Thus, “polymer” should not be treated as a uniform mechanical category.

The material-dependent findings are also biologically plausible in light of the finite element evidence reported by Eskibağlar et al. (2024).(5) Their 3D FEA revealed that the stainless steel clamps induced greater von Mises stress in the tooth than the PEEK clamps in the various access cavity models. The predicted clamp forces were also higher for stainless steel than PEEK. The authors reported higher stress values under stainless-steel loading for all modelled cavity configurations . Although their study evaluated PEEK rather than PLA and assessed stress distribution rather than surface roughness, the findings provide a mechanical framework for interpreting the present results. A clamp material and geometry capable of transmitting greater localized force to a small cervical

contact area could plausibly produce greater surface alteration.(9) The lower percentage changes observed with the novel PLA clamp are compatible with this interpretation, but the present experiment did not directly measure clamp force, contact pressure, or stress distribution. Therefore, a causal relationship between the mechanical properties of PLA and the observed roughness pattern cannot be established from the current data alone.

Clamp geometry may be equally important. The CEJ is a transition zone between enamel and cementum with variable surface morphology, and the effective contact area of a clamp determines how the applied force is distributed.The serrated clamp may provide more concentrated contact points than the smooth-edged design, and thus promote localised mechanical interaction.(4) Kayalidere et al. (2025) reported different morphological patterns on scanning electron microscopy, with scratch-type defects related to the polymer clamp and crack-like changes related to metal clamps.(7) The present study relied on profilometric Ra measurements and therefore cannot determine whether the observed numerical changes corresponded to scratches, localized indentation, microcracks, or other morphological alterations. The lower Ra change observed with the novel PLA clamp should consequently be interpreted as reduced measured roughness alteration rather than definitive evidence of an absence of microscopic damage.

The duration-dependent findings deserve particular attention. If clamp application time were the dominant determinant of CEJ alteration, a progressive increase in percentage change would be expected across 30 minutes, 1 hour, and 2 hours. Such a consistent temporal relationship was not observed. The significant between-group difference occurred at 1 hour, whereas the comparisons at 30 minutes and 2 hours were nonsignificant. This is broadly compatible with Kayalidere et al. (2025), who concluded that increasing application duration did not produce a consistent additional effect on the extent of roughness alteration.(7) The absence of a simple duration-response pattern suggests that clamp–surface interaction may depend more strongly on the combination of clamp material, geometry, adaptation, and localized force concentration than on elapsed contact time alone. Because only three discrete durations were examined, however, the present findings should not be interpreted as evidence that prolonged application is clinically inconsequential.

From a clinical perspective, the findings indicate that clamp design can influence measurable CEJ surface alteration, with the novel PLA clamp demonstrating the lowest percentage change at each tested duration. However, the statistically significant between-group difference was confined to the 1-hour assessment and specifically involved the serrated stainless-steel and novel PLA designs.(10) Thus, selection of a clamp should consider not only material but also jaw geometry, adaptation, retention, and the condition of the cervical tooth surface.

The principal strengths were the standardized CEJ measurement region, repeated profilometric assessment of the same surface, inclusion of four clamp designs, evaluation across three application periods, and use of specimen-level percentage change as the principal comparative outcome. The study is nevertheless limited by its in vitro design, relatively small number of specimens within each clamp-duration combination, use of extracted teeth rather than teeth under physiologic oral conditions, and reliance on Ra as a surface descriptor. Mechanical variables such as clamp force, contact pressure, and stress distribution were not measured, and microscopic assessment was not performed; consequently, the structural nature and clinical significance of the observed roughness changes cannot be established.(6)

Future studies should use profilometry in combination with SEM or other high-resolution surface characterisation to identify the morphology underlying changes in Ra. Further studies, either mechanical testing or FEA, could clarify the effect of clamp material, jaw geometry, and contact pressure on CEJ stress. More extensive studies should also evaluate a broader range of tooth morphologies and application periods, particularly whether the decreased surface alteration with atraumatic designs is compensated by sufficient retention and clinically acceptable rubber dam performance.

CONCLUSION

Within the limitations of this in vitro study, rubber dam clamp design affected the CEJ surface roughness alteration at the 1-hour application period, with the novel PLA clamp exhibiting the lowest percentage change and the serrated stainless-steel clamp the highest. But no significant between-group differences were observed at 30 min or 2 h. The results suggest that changes in cervical surface may be influenced by the clamp material

and geometry and further studies combining microscopic and mechanical analysis are required to determine the clinical relevance of these changes.

REFERENCES

1. Wang Y, Li C, Yuan H, Wong MC, Zou J, Shi Z, et al. Rubber dam isolation for restorative treatment in dental patients. Cochrane Database Syst Rev . 2016 Sept 20;9(9):CD009858. DOI: 10.1002/14651858.CD009858.pub2
2. Ahmad IA. Rubber dam usage for endodontic treatment: a review. Int Endod J . 2009 Nov;42(11):963–72. DOI: 10.1111/j.1365-2591.2009.01623.x
3. Nasser A. Rubber dam isolation - when and why to use it? Part 1. BDJ Student . 2021 Jan;28(2):40–1. DOI:10.1038/s41406-021-0201-y
4. Vandana KL, Haneet RK. Cementoenamel junction: An insight. J Indian Soc Periodontol . 2014 Sept;18(5):549–54. DOI: 10.4103/0972-124X.142437
5. Eskibağlar M, Erdem S, Karaağaç Eskibağlar B, Kaman MO. Evaluation of the forces applied by rubber dam clamps on mandibular first molar teeth with different endodontic access cavities: a 3D FEA study. PeerJ . 2024 Aug 26;12:e17921. DOI: 10.7717/peerj.17921
6. Tantisareerat N, Phumpatrakom P, Wongwitthayakool P, Phupewkeaw N, Lertvachirapaiboon C, Krajangta N. Fabrication and evaluation of polypropylene/natural rubber dental clamps: a model-based comparative study of isolation quality and user satisfaction. BMC Oral Health. 2026 (Article in Press); DOI: 10.1186/s12903-026-09847-6
7. Erden Kayalidere E, Sahin M, Korkut B, Mudok T, Caliskan Yanikoglu F. Surface Roughness on Cementoenamel Junction After Rubber-Dam Clamp Application. J Esthet Restor Dent . 2025 Apr;37(4):1004–12. DOI: 10.1111/jerd.13370
8. Spreafico R, Marchesi G, Turco G, Frassetto A, Di Lenarda R, Mazzoni A, et al. Evaluation of the In Vitro Effects of Cervical Marginal Relocation Using Composite Resins on the Marginal Quality of CAD/CAM Crowns. J Adhes Dent . 2016;18(4):355–62. DOI: 10.3290/j.jad.a36514
9. Hussein A, Ali D, El-ezz AA. Evaluation of stress distribution in endodontically treated premolars restored with two different designs of overlay restorations: A finite element analysis. Research Square; 2026 (Ahead of Print). DOI: 10.21203/rs.3.rs-8680417/v1
10. Fetisova AA, Surmeneva MA, Surmenev RA. Advanced Design Concepts for Shape-Memory Polymers in Biomedical Applications and Soft Robotics. Polymers (Basel) . 2026 Jan 13;18(2). DOI: 10.3390/polym18020214