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ORIGINAL ARTICLE

Comparison of Reverse Sandwich Restorations Versus Composite Fillings for the Restoration of External Cervical Resorptions: An *In-Vitro* Study

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ABSTRACT

Objective: The aim was to compare the “reverse sandwich restoration” to resin composite restorations regarding marginal adaptation, fracture resistance, favourable/unfavourable fractures in the management of external cervical resorption.

Methods: Forty-eight extracted maxillary central incisors were selected and endodontically treated. Cervical regions of the labial root surfaces received simulated resorptive defects and were restored as three randomly allocated groups: Reverse Sandwich Restoration (resin composite + resin-modified glass ionomer) (RSR); resin composite restoration (COMP), and no restoration (NR). Each group was further divided into two subgroups (n=8 each): Thermomechanical Aging (TA) (equivalent to one year) and No Aging (NA). Marginal adaptation was scored by scanning electron microscopy. Fracture resistance was tested using a universal testing machine. Favourable versus unfavourable fractures were classified based on fracture extent.

Results: TA decreased the marginal adaptation for both RSR and COMP. Mean fracture resistance per groups were: RSR-NA 1522.4±94.9N, RSR-TA 939.6±72.9N, COMP-NA 1197.6±95.7N, COMP-TA 870.4±86.3N, NR-NA 1057.1±88.1N, and NR-TA 836.6±81.9N, respectively. Fracture resistance was the highest for RSR-NA compared to all other groups ($p<0.05$). TA decreased the fracture resistance in all groups ($p<0.05$), there was no significant difference between RSR and COMP regarding fracture resistance and favourable/unfavourable fractures ($p>0.05$).

Conclusion: RSR provided comparable results to resin composite fillings to restore artificial cervical defects pertaining to marginal adaptation, fracture resistance, and favourable versus unfavourable fractures. RSR is preferable due to its inherent biocompatibility to the periodontium.

Keywords: Dental marginal adaptation, external cervical resorption, reverse sandwich restoration, root reinforcement, root resorption

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HIGHLIGHTS

- RSR reinforced the simulated resorptive defects comparatively like resin composites.
- RSR and resin composites displayed similar marginal adaptation in the cervical region.
- RSR is preferred to resin composite restorations in the event of failure, as a comparatively high percentage of favourable failure patterns was identified.

INTRODUCTION

Root resorption is a pathological process involving the destruction of hard dental tissues. It may be caused by trauma, orthodontic treatment, bleaching, or periodontal diseases (1). Root resorption can be broadly classified as internal or external (2). External Cervical Resorption (ECR) is a complicated, aggressive, and rare form of external root resorption. Heithersay (3), named it 'invasive cervical resorption', due to its invasive and aggressive nature and classified it based on the lesion extent within the tooth. Recently, Patel et al. (4) formulated a 3-D classification using cone-beam computed tomography. It considers the ECR lesion height [1: at cementoenamel junction (CEJ) level or supracrestal, 2: spreading into the coronal third of the root and subcrestal, 3: spreading into the mid-third of the root, 4: spreading into the apical third of the root]; circumferential spread (A: ≤90°, B: ≤180°, C: ≤270°, D: >270°) and proximity to the root canal (d: lesion confined to dentine, p: probable pulpal involvement).

ECR usually occurs just below the epithelial attachment of the tooth in the cervical region (1) and can be challenging to diagnose and manage. The long-term success of ECR treatment depends on careful case selection and operative skills. ECR is often only detected when the lesion has reached an advanced stage and symptoms of pulpal involvement arise (2). Management depends on the extent, location, pulpal involvement, and restorability of the tooth (5). Endodontic treatment might be required in cases where the lesion has perforated the root canal. Usually, a full-thickness mucoperiosteal flap is elevated surgically; the resorptive lesion is curetted, restored, and finally, the flap is replaced (6). Heithersay et al. (7) recommended topical application of a 90% aqueous solution of trichloroacetic acid directly on the ECR defect, which causes coagulation necrosis of the resorptive tissue, without damage to the adjacent periodontal tissues while infiltrating small channels and recesses of an ECR that could otherwise not be reached by mechanical instrumentation. A tooth will then receive a definitive restoration.

The ideal requirements of a restorative material are to seal the defect, reinforce root integrity, resist fracture against masticatory forces, and demonstrate biocompatibility towards the surrounding tissues, all directly affecting the longevity of a tooth with ECR. Adhesive materials have shown to reinforce roots affected by ECR, albeit to a varying degree (8), but unfortunately, they often cause irritation to gingival and subgingival issues. Non-adhesive materials are unable to strengthen a root to the same extent (6). Vinothkumar et al. (9) introduced the Reverse Sandwich Restoration (RSR), a bi-layered combination of restorative materials proposed to display both properties of root reinforcement and biocompatibility to the periodontium. This restoration consists of a 1–1.5mm thick layer of microfilled resin composite towards the pulp for root reinforcement and an outer layer of resin modified glass ionomer cement (RMGIC) for enhanced biocompatibility towards the periodontium (9).

Various materials have been tested regarding their ability to provide fracture resistance, including RMGIC, resin composites, flowable composites, Giomer, Biodentin, or Mineral Trioxide Aggregate (MTA) (6, 8). However, there is limited knowledge regarding root reinforcement for ECR defects after restoration with RSR, and how masticatory forces may affect its marginal integrity. The primary objective of this study was to compare fracture resistance and mode of fracture of teeth restored with different cervical restorations for the management of external cervical resorption in an *in-vitro* model. The secondary objective was to evaluate the marginal adaptation of the two experimental filling methods used for the restoration of ECR. The first null hypothesis tested was that there is no difference in fracture resistance and marginal adaptation between different cervical restorations. The second hypothesis tested was that there is no difference in mode of fracture between different cervical restorations.

MATERIALS AND METHODS

The study was conducted in accordance with the Declaration of Helsinki. This study was approved by the Scientific Review Board (Ref. No. SRB/SDC/ENDO-1904/21/032 dated 23/12/2023) and Institutional Human Ethics Committee (Ref. No. IHEC/SDC/ENDO-1904/21/290 dated 23/12/2023).

Sample Size Calculation

G*Power 3.1 (Heinrich-Heine-University, Düsseldorf, Germany) was used to calculate the needed sample size. Calculations were based on Bolli et al. (8), who compared the fracture resistance of root canal treated teeth with artificial cervical resorption cavities after restoration with various restorative materials. Parameters were set to $\alpha=0.05$ and 90% power and considering an effect size of 0.48, a total of 47 specimens were indicated as required for observing significant differences. A total of 48 samples (8 in each testing group) were set for the study.

Specimen

Forty-eight freshly extracted non-carious single-rooted human permanent maxillary central incisors with straight roots and completely formed apices were stored in saline at 30°C until use. Teeth with caries, fracture lines or cracks, pre-existing resorptive defects, or previous root canal treatment were excluded. The tooth dimensions were measured with digital calipers (Mitutoyo, Hiroshima, Japan) for standardisation. Mean values for crown length, root length, and the mesio-distal and bucco-lingual root widths were 10.5 mm, 13.0 mm, 6.75 mm, and 6.0mm, respectively. Teeth with more than 20% deviation from the above values were excluded from the study (10). Each tooth was observed under a stereomicroscope at 20x magnification (Leica Micro-system Imaging Solutions, Cambridge, UK) to ensure the absence of cracks or micro-fractures and was stored in distilled water at 37°C.

Root Canal Treatment

After access cavity preparation, the root canals were instrumented to working length using ProTaper Gold (Dentsply Maillefer, Ballaigues, Switzerland) up to size F5 according to the manufacturer's instructions. During instrumentation, canals were irrigated with 3 ml of 2.5% NaOCl (Prime Dental Products Pvt. Ltd., Thane, India) using a 27G hypodermic needle and lubricated with ethylenediaminetetraacetic acid (RC Help, Prime Dental Products Pvt. Ltd., India). The canals were also irrigated with saline after instrumentation with each file size. Following chemico-mechanical preparation, the canals were dried with absorbent paper points (Dentsply Maillefer, Switzerland) and filled using lateral compaction with gutta-percha (Dentsply Maillefer) and AH Plus Sealer (Dentsply Maillefer, Switzerland). The canal orifices were sealed with resin-modified glass ionomer cement (Fuji II LC; GC Corporation, Tokyo, Japan), and the access cavity was restored with resin composite (Tetric N Ceram, Ivoclar Vivadent, Schaan, Liechtenstein) (11).

Simulated Resorptive Defects

Standardized cavities (Fig. 1) were prepared on the labial root surface extending symmetrically towards the crown and root across the CEJ using a round bur (012 Hi-Di 521, medium grit; Dentsply, Weybridge, UK) according to Patel's classification (4) to simulate the resorptive defect (Class 1Ad). All cavities were standardized in the shape of scooped-out hemispherical lesions (4.0 mm diameter and 2.0 mm depth) with the help of a resin template (12). The resin template had been fabricated by capturing an optical impression of a representative cavity using an intraoral scanner (CEREC Primescan Intraoral Scanner, Dentsply Sirona, Charlotte, NC, USA), and printed using a 3D printer (NextDent 5300, 3D Systems, Netherlands).

Groups

All teeth were labeled with serial numbers and rank ordered according to size for allocation. The teeth were chosen for each group selectively based on rank to meet similar average dimensions of teeth as calculated earlier for the inclusion criteria. Randomization was avoided as it may result in a biased distribution of teeth. The materials used for the restorations were blinded during the randomized distribution.

Reverse Sandwich Restoration (RSR): The resorptive defect was coated with one-step self-etch adhesive (G Bond; GC Corporation, Tokyo, Japan) according to the manufacturers' instructions, and light cured for 10 seconds. An intial layer of mi-

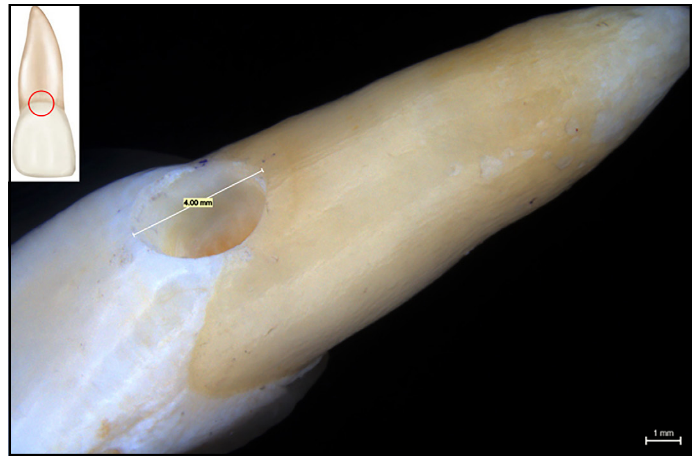

Figure 1. Human maxillary central incisor showing the simulated resorptive defect measuring 4mm in diameter. Inset showing the mesiodistal and apicoincisal position of the preparation

croparticle filled resin hybrid composite (Gaenial Anterior, GC Corporation, Japan) to a thickness of about 1.5 mm was placed and light cured for 20 seconds. A final layer of RMGIC (Fuji II LC; GC Corporation, Japan) was applied in the remainder of the defect (0.5 mm) to a smooth finish using cervical matrix and light cured for 20 seconds

Resin composite Restoration (COMP) – Following the manufacturer's directions, a one-step self-etch adhesive (G-Bond; GC Corporation, Japan) was applied and exposed to light for 10 seconds before curing. Microparticle filled composite (Gaenial Anterior, GC Corporation, Japan) was used to fill in the resorptive flaws, and it was smoothed down with a cervical matrix before being light cured for 20 seconds.

Control(NR) – The simulated defects were left unrestored.

All the specimens were placed in light-proof containers and allowed to sit for 24 hours at 37°C and 100% humidity in an incubator.

Each group (n=16) was further divided into two subgroups of 8 samples each.

Subgroup TA- Samples were subjected to Thermomechanical Aging (TMA) as explained below.

Subgroup NA- Samples were not subjected to aging treatment.

Thermomechanical Aging

Twenty-four samples from Groups RSR, COMP, and NR, were subjected to TMA in a chewing simulator with an integrated thermal cycler (Fig. 2a) (CS-4.4, SD Mechatronik, Gmbh, Germany). A specialized mold designed for use with the chewing simulator was used to mount the specimens (Fig. 2b). Customized spherical stainless-steel antagonists of a 2.0 mm tip diameter were manufactured to exert the force during the chewing simulation. All samples were subjected to 250,000 cycles of TMA with a 5.0 kg (49 N) load at every chewing cycle and 2000 thermal cycles alternating between 5°C and 55°C, with a dwell time of 30 seconds owing to a one-year period of aging.

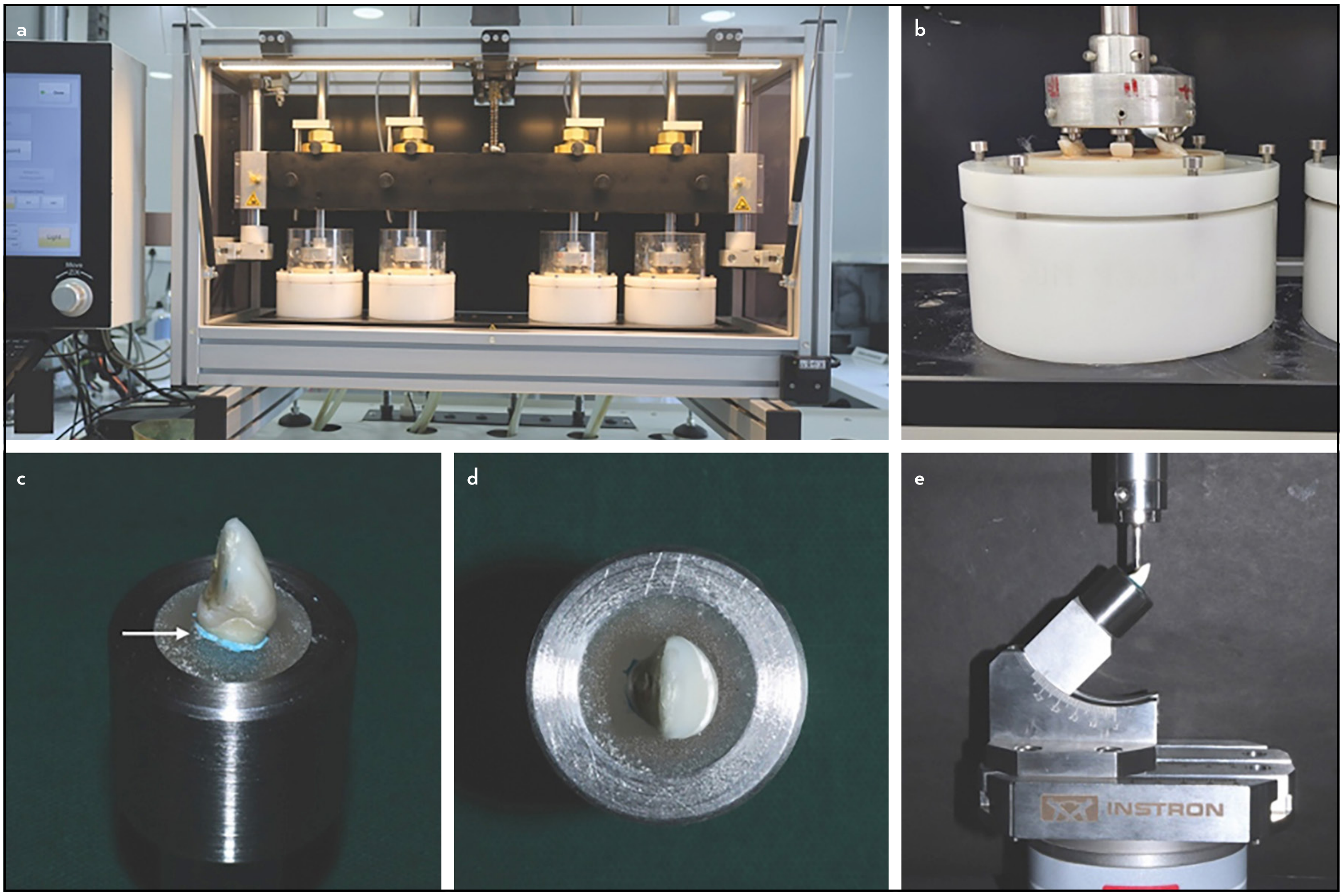

Figure 2. Sample testing in chewing simulator and Instron machine. (a) Integrated thermal cycler. (b) Specimen mounted in customized mold positioned in chewing simulator. (c) Extracted tooth mounted in acrylic jig. Note simulated periodontal ligament (arrow). (d) Acrylic jig, top view. (e) Jig with sample tooth mounted in the Instron machine at an angle of 45°

Marginal Adaptation

Two samples from each experimental group (RSR-NA, RSR-TA, COMP-NA and COMP-TA) were qualitatively evaluated by two operators (KD and JS) for marginal adaptation under a scanning electron microscope (SEM) (Jeol IT800 SHL FE-SEM, Tokyo, Japan) at a standard 200x magnification. The specimens were mounted on aluminum stubs and then platinum sputter coated prior to the assessment of the tooth-restoration margins. The maximum gap was measured for each sample and scored based on the following criteria adopted from Aggarwal et al. (13) and Ebaya et al. (14):

Score 1: No marginal gap

Score 2: Maximum marginal gap not exceeding 30μm.

Score 3: Maximum marginal gap exceeding 30 μm.

Fracture Resistance Testing

All samples were subjected to fracture resistance testing under oblique loading. The root portion of each tooth sample was wrapped with a single layer of aluminum foil up to the CEJ. A customized stainless-steel jig was manufactured to mount the specimens for evaluation of fracture resistance (Fig. 2c, d). The jig was filled with clear acrylic resin and teeth specimen wrapped in aluminum foil was immersed into the unset resin. To simulate the biological width 2.0 mm below the CEJ was not covered with acrylic. After the resin had completely set, the tooth was dislodged and the aluminum foil spacer was removed. The root surfaces were coated with a light body polyvinyl siloxane impression material (Elite HD+, Zhermack, Polesine, Italy), and the tooth was immediately reinserted into the artificial resin socket up to the CEJ to simulate periodontal ligament. The custom jig was then mounted into the lower arm of the universal testing machine (Instron ElectroPuls E3000 UTM, UK) so that the lingual aspect of the crown faced a 4.0 mm diameter metal indenter at an angle of 45° to the long axis of the tooth (Fig. 2e). Increasing load until failure was applied to the palatal surface 3.00 mm from the incisal edge with a crosshead speed of 0.5 mm/min. The maximum force required to fracture the specimen was recorded in Newtons (N).

Fracture Investigation

The fractured samples were then reviewed by two operators (KD, JS) under a stereomicroscope (Leica Micro-system Imaging Solutions, Cambridge, UK) at 20x magnification to examine the fracture lines and categorize them into favourable and unfavourable fracture patterns. A fracture line coronal to 1mm below the CEJ was classified as favourable (restorable) and unfavourable when the fracture line was apical to 1mm below the CEJ (non-restorable) (6).

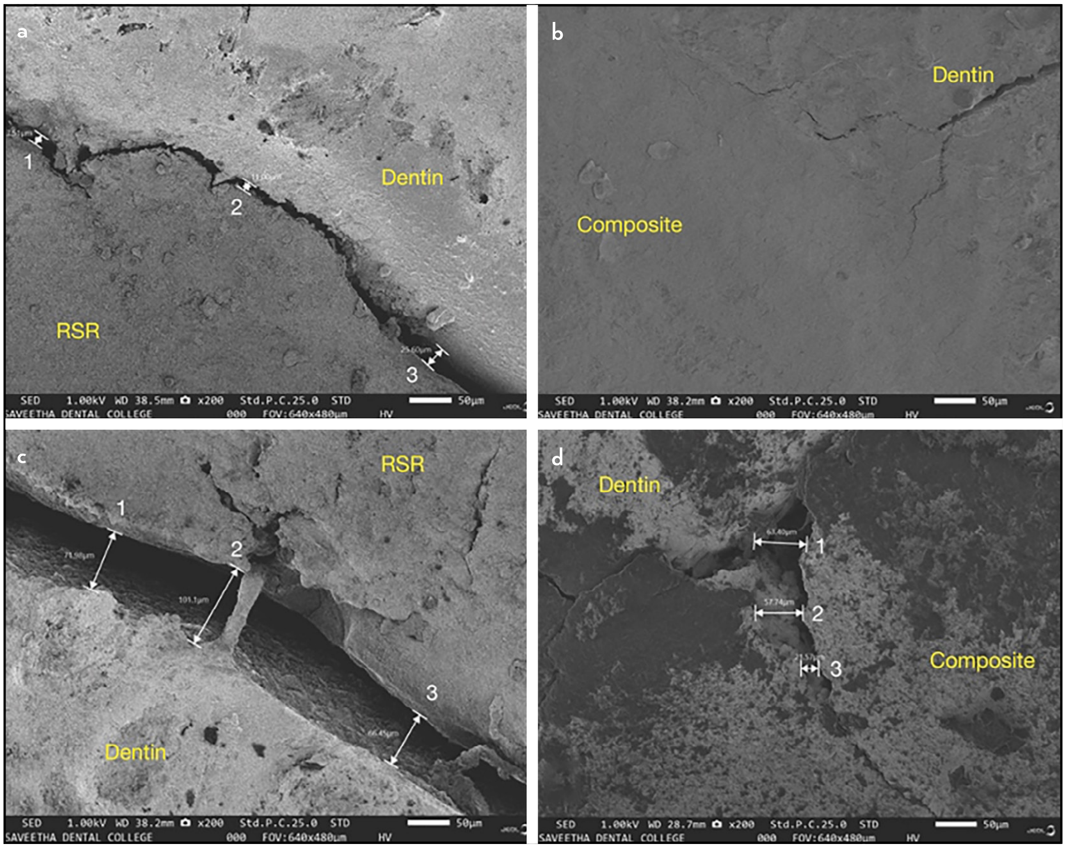

Figure 3. Marginal evaluation of restorations under X200 magnification, representative samples. (a) RSR-NA; score 2; [1] = 13.51µm, [2] = 11.06µm, [3] = 25.06µm. (b) COMP-NA; score 1. (c) RSR-TA; score 3; [1] =71.98µm, [2] = 101.1µm, [3] = 66.45µm. (d) COMP-TA; score 3; [1] = 63.40µm, [2] = 57.74µm, [3] = 21.57µm

Statistical Analysis

The results were analyzed using SPSS 18 software (SPSS Inc. Ver.18.0. Chicago, IL, USA). A paired t-test was used to analyze the fracture resistance within each group. One-way ANOVA and Posthoc Tukey tests were carried out for inter-group comparisons. A non-parametric Mann-Whitney U-test was used to assess favourable versus unfavourable fractures. The level of significance was set at 5%, and p<0.05 was considered statistically significant.

RESULTS

Marginal Adaptation

SEM images of both samples revealed a maximum gap not exceeding 30 µm for the non-aged RSR (RSR-NA, score 2; Fig. 3a). No gap was observed for the non-aged resin composite restoration (COMP-NA, score 1; Fig. 3b). However, for both thermomechanically aged restorations COMP-TA (Fig. 3c) and COMP-TA (Fig. 3d), a maximum gap at the tooth-restoration junction exceeding 30µm (score 3) was identified in both the samples.

Fracture Resistance

Mean fracture resistance values are shown in Table 1. The fracture resistance of the teeth was maximum for RSR-NA and the least for NR-TA (Fig. 4). All aged groups demonstrated significantly lower fracture resistance compared to the paired non-aged groups (p=0.001). A statistically significant difference was observed in the fracture resistance among all three groups (One-way ANOVA; p=0.001). The restored experimental groups showed higher fracture resistance compared to that of the unrestored control groups (Fig. 4). RSR-NA showed significantly better fracture resistance than COMP-NA (p=0.001; Table 1). Among the thermomechanically aged groups, RSR-TA showed the maximum resistance to fracture, followed by groups COMP-TA and NR-TA, although the difference was not statistically significant (p>0.05; Table 2).

Fracture Investigation

All specimens underwent oblique crown-root fractures at the cervical region. Overall, 77.1% of the specimens across all

TABLE 1. Comparison of fracture resistance before and after thermomechanical aging within each group

Groups	Mean±SD	Mean difference	p*
RSR-NA	1522.4±94.9	582.7	0.001
RSR-TA	939.6±72.9		
COMP-NA	1197.6±95.7	327.2	0.001
COMP-TA	870.4±86.3		
NR-NA	1057.1±88.1	220.5	0.001
NR-TA	836.6±81.9		

*: Paired t test, significance at p<0.05. SD: Standard deviation, RSR: Reverse sandwich restoration (composite+resin-modified glass ionomer), NA: No aging, TA: Thermomechanical aging (equivalent to one year), COMP: Composite restoration, NR: No restoration

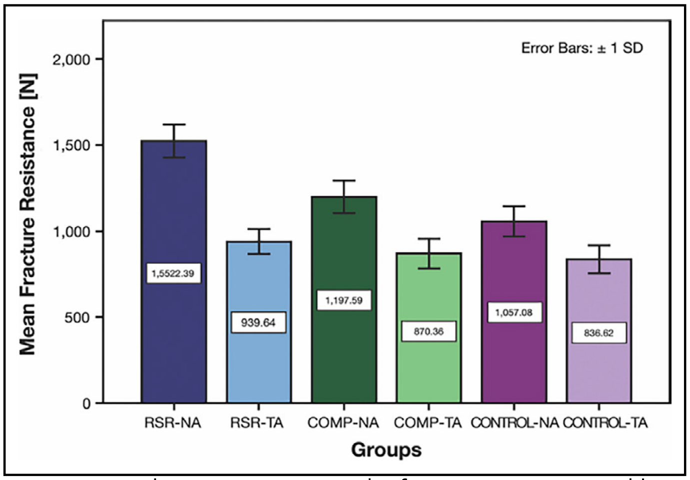

Figure 4. Bar diagram representing the fracture resistance to oblique load for the experimental and control groups

SD: Standard deviation, RSR: Reverse sandwich restoration (composite+resin-modified glass ionomer), NA: No aging, TA: Thermomechanical aging (equivalent to one year), COMP: Composite restoration

groups showed unfavourable fractures, while 22.9% showed favourable fractures. The highest number of favourable fractures was seen in RSR (37.5%), followed by COMP (25%), and the least in NR (6.25%) (Table 3). Within each group, a higher number of favourable fractures was seen in subgroup NA as compared to subgroup TA. The percentage of favourable fractures in each group was; RSR-NA (50%), RSR-TA (25%), COMP-NA (37.5%), COMP-TA (12.5%), and NR-TA (12.5%). NR-NA showed all unfavourable fractures. Amongst the thermomechanically-aged groups, there was no significant differences (Mann-Whitney U-test), in detail, RSR-TA versus COMP-TA (U value = 28, Z score 0.36757, p=0.71138.), COMP-TA vs CON-TA (U value = 32, Z score 0.05251, p =0.96012), and RSR-TA vs CON-TA (U value = 28, Z score 0.36757, p=0.71138).

DISCUSSION

Options for the treatment of moderate to severe ECR include external repair with (15) or without endodontic therapy (16); internal repair (17); reimplantation (18), and have reported good survival rates for the affected teeth (2).

For our study, we opted for freshly extracted maxillary central incisors, as ECR is common in maxillary incisors due to a high rate of traumatic injuries (2). The intrinsic quality of dentine may differ between teeth, and varied biochemical properties in relation to age and ethnicity may alter the resistance to fracture leading to an inaccuracy of results (19). To overcome this potential problem, we calculated the mean fracture resistance of several samples for each group. Since ECR defects are often diagnosed at a more advanced stage due to their asymptomatic nature (8), endodontic therapy is often part of the treatment plan, leading to the decision to perform root canal treatment on all specimens in the study.

In a similar *in-vitro* study (8), the authors compared the fracture resistance to oblique loading on simulated ECR defects in maxillary central incisors restored with Giomer, RMGIC, conventional GIC and flowable resin composite. Although they concluded that Giomer showed significantly better results compared to the other materials, a major limitation of the study was the absence of periodontal ligament simulation. Soares et al. (20) concluded that periodontal ligament simulation influences the mode of fracture during fracture resistance tests. The periodontal ligament simulation in our study followed a previously established model using aluminum foil, polyvinyl siloxane material and acrylic resin (21).

Endodontic treatment may account for reduction in fracture resistance (7). Consequently, root fractures are one of the common causes of failure in teeth with ECR. In many instances after ECR repair, obtaining a sound ferrule in the labial aspect is challenging, making it very difficult to place full-coverage crowns. This makes the choice of restoration an important factor regarding survival of the tooth (8).

In general, the results showed that both restorations had a better resistance to fracture than the control group. The RSR group showed significantly better fracture resistance as compared to the COMP particularly when tested without aging. RSRs possess several desirable properties. These include the ability to reinforce the tooth due to the microfilled resin composite, a thermal expansion coefficient close to that of tooth structure, and very good biocompatibility (9). The biocompatibility of RMGIC has been studied widely by several authors *in-vitro* as well as *in vivo* (11, 22). It was concluded that most RMGICs may be considered biocompatible, although Vitremer was found to be cytotoxic and less biocompatible. In a recent case report for the surgical management of ECR (23), the authors stated that although MTA had the best biocompatibility as compared to composite, RMGIC demonstrated better periodontal reattachment. Moreover, the modulus of elasticity of RMGIC is closer to that of dentine which helps to resist bending forces (24). The downside of MTA is its rough surface which encourages subgingival plaque formation. MTA cannot strengthen the tooth structure because it is not a strong substance and can be partially scraped off while mechanically cleaning of the root

TABLE 2. Comparison of fracture resistance between different groups

Unaged			Aged		
Groups	**Mean difference**	**p***	**Groups**	**Mean difference**	**p***
RSR-NA vs COMP-NA	324.8	<0.001	RSR-TA vs COMP-TA	69.3	0.61
COMP-NA vs NR-NA	140.5	0.027	COMP-TA vs NR-TA	33.7	0.97
RSR-NA vs NR-NA	465.3	<0.001	RSR-TA vs NR-TA	103.0	0.19

*: Posthoc Tukey test, significance at p<0.05

TABLE 3. Prevalence of fracture types among the groups

Groups	n	Favourable		Unfavourable	
		n	%	n	%
RSR-NA	8	4	50	4	50
RSR-TA	8	2	25	6	75
COMP-NA	8	3	37.5	5	62.5
COMP-TA	8	1	12.5	7	87.5
NR-NA	8	0	0	8	100
NR-TA	8	1	12.5	7	87.5

CTRL: No restoration

surface during scaling (25). In our study, since we placed the specimens at a 45° angle to the load, bending forces would have acted on the cervical area. Since the modulus of elasticity of RMGIC (~20 MPa) is close to that of dentine (~18 MPa) (26), it would have been able to withstand the forces better without giving way. This, in addition, the excellent compressive strength of microfilled resin composite (27) could have contributed to the good performance of the RSR group.

Another parameter assessed was the effect of TMA on the marginal adaptation of the restorations. We inferred that the marginal adaptation was compromised in samples following TMA. Among the two restorations, COMP showed better marginal adaptation as compared to RSR before TMA while both performed almost similarly after TMA, which were in accordance with the results by Irie et al. (28). This could be attributed to the fact that RMGIC demonstrates viscoelastic behavior during deformation (29), which allows for stress relief in form of energy dissipation. Higher stress states cause polymerization shrinkage eventually leading to marginal gap formation (29). However, after a complete setting reaction has occurred, the polymerization shrinkage levels in RMGIC gradually decrease as a result of either water absorption or viscoelastic properties (30). However, resin composite materials usually have a gradual increase in polymerization shrinkage, which could be attributed to a slower continued rate of polymerization of residual monomer retained after initial light curing (30). Moreover, viscoelastic properties of resin composites renders them inefficient in reducing the contraction stresses during the early stages of setting (31). Aged samples demonstrate poorer material properties, artificial aging affects marginal adaptation (32), bond strength (33), and resin-tooth interface degradation (34). Limited literature is available on the effect of aging on the fracture resistance of teeth. The fracture resistance of the artificially aged samples was significantly lower compared to the non-aged counterparts, implying that TMA had an impact on the fracture resistance. This is in accordance with previous studies on dentine (19, 34) as well as indirect restorations (35). After aging, the maximum force to fracture was higher for teeth restored with RSR, followed by COMP and lastly the unrestored teeth (NR). However, there was no significant difference in the fracture resistance between groups RSR-TA and COMP-TA. Therefore, clinically, the long-term root reinforcement offered by RSR for the tooth in function may be at least clinically comparable with that of composite.

In the current study, most of the specimens showed catastrophic, unfavourable fractures. Maximum stresses are concentrated at the CEJ of maxillary central incisors, with the buccal side undergoing compressive stresses while the palatal side is subject to tensile stresses as the tooth bends. This could be attributed to the difference between the crown's higher rigidity and the root lower rigidity (36). Since RMGIC's modulus of elasticity is closer to that of dentine than it is to enamel, the restoration bends with dentine and is therefore better able to absorb induced stresses at the dentinal end rather than the enamel end. Due to the weak enamel end, which makes it more likely for fracture lines to pass through, the RSR group experiences significantly more favourable fractures (24). Hence the first null hypothesis could not be rejected and the second one was rejected. Under the standard testing conditions in this study, although TA had an impact on the fracture resistance of experimental groups making them insignificant to that of NR group, the nature of restorative materials would have created a difference in the fracture pattern and nature of crack propagation. Moreover, increase or decrease in size of the restoration depending on the extent of resorptive defect (height, circumferential spread, and proximity to the pulp) (4) might have an influence on the fracture resistance of the specimens.

One of the major strengths of this study was mimicking the oral environment and conditions by simulating the periodontal ligament, placing the teeth at an angle of 45° to the load and TMA of the teeth (6). Although the samples were subjected to TMA, longer periods of thermomechanical aging corresponding to 5–10 years of clinical function would have given a better prediction of the long-term clinical performance of the restorations. The use of artificial lesions differs from natural resorptive defects, as the latter exhibit unique features such as dentinal tunnels and intact pre-dentine isolating the resorptive process from root canal (37). The experiments of this study were carried out *in-vitro* and circular cavities were prepared to standardize the preparations, which may not conform to clinical presentation of the defect. Although a resin template was used to verify the dimensions of the simulated resorptive defects, a complete standardization was not possible. However, the intrinsic variation in the dentine quality of samples was compensated by calculating the mean for the data.

Further *in-vitro* studies and clinical trials are required to compare the marginal leakage and overall long-term clinical performance of RSR restorations respectively with other contemporary restorations for ECR defects

CONCLUSION

The reverse sandwich restorations showed less unfavourable fractures compared to resin composite restoration, which may be clinically significant. There was no difference in marginal adaptation and fracture resistance between RSR and resin composite restoration after thermomechanical aging. Reverse sandwich restorations may be considered a suitable alternate technique for the restoration of ECR defects.

Disclosures

Conflict of interest: The authors deny any conflict of interest.

Ethics Committee Approval: This study was approved by The Scientific Review Board (Date: 23/12/2023, Number: SRB/SDC/ENDO-1904/21/032) and Institutional Human Ethics Committee (Date: 23/12/2023, Number: IHEC/SDC/ENDO-1904/21/290).

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