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Cervical Margin Relocation: Effect of Crown, Endocrown and Onlay Margin Location and Material Type on the Fracture Resistance of Endodontically Treated Molars

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Abstract: This study aimed to evaluate the fracture resistance of endodontically treated molars restored with ceramic indirect restorations with and without cervical margin relocation. A total of 120 extracted human maxillary molars were used after MOD cavities preparations with the mesial boxes located 2 mm below CEJ. Specimens were randomly assigned to six groups according to the margin location of each indirect restoration type (n = 20); crown without CMR, crown with CMR, endocrown without CMR, endocrown with CMR, onlay without CMR, and onlay with CMR. Mesial proximal boxes of the MOD cavities were elevated with composite resin in cervical margin relocation groups. Each group was further divided according to indirect restoration material (n = 10); CEREC Tessera and Celtra Press. The specimens were subjected to fracture resistance testing in a universal testing machine. Fracture analysis was performed using stereo and scanning electron microscopes. Data were analyzed by using 3-way ANOVA, 1-way ANOVA and the Tukey HSD tests ($\alpha = 0.05$). The mean fracture resistance values ranged between 2136.57 and 950.47 N. Significantly higher values were detected among Celtra Press than Cerec Tessera in crown restorations. Unrestorable fracture patterns were seen through all study groups. Crown restorations represented the best restorative option in terms of fracture resistance. Cervical margin relocation adversely affected fracture resistance. However, the material of the indirect restorations had no significant impact on fracture resistance.

Keywords: endodontically treated teeth; cervical margin relocation; dental materials: advanced lithium disilicate; prosthodontics zirconia reinforced lithium silicate; fracture resistance

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1. Introduction

The indirect restoration of large defects with deep cervical margins can represent a challenging clinical situation, including difficulties in tooth preparation, impression taking, isolation and adhesive cementation procedures [1,2]. Since the margins of these defects often extend beyond CEJ, a possible violation of the biologic width with restorations can lead to inflammation and subsequent bone resorption [3]. Surgical crown lengthening and orthodontic extrusion are commonly indicated in these situations to preserve healthy periodontal tissue conditions [4]. However, these procedures are costly, time consuming, and can result in the removal of more tooth structure to receive the restorative material [5]. A more conservative approach called cervical margin relocation (CMR) was introduced by Dietschi and Spreafico in 1998 [6]; Magne [7] referred to the same technique as deep margin elevation (DME). Cervical margin relocation elevates the cervical margin of a sub-gingival preparation to a supra-gingival level with a composite resin material by using a well-adapted and sealed matrix band [8]. It can be performed before the placement of indirect restorations to facilitate the following restorative procedures [9]. Recent in vitro studies on cervical margin relocation indicated that it can represent a valuable technique for the restoration of deep cavities reaching below CEJ with indirect restorations [10–13].

Root canal treatment can add additional complexities for the application of a cervical margin relocation technique in combination with indirect restorations [2]. Biomechanical changes that occur following root canal treatment along with loss of tooth structure during cavity preparation and caries removal can increase tooth fragility and the risk of mechanical failures [14–16]. Endodontically treated teeth (ETT) with mesio-occluso-distal (MOD) defects can represent maximal tooth fragility [17–19]. Full-coverage crown restorations are mainly suggested for the restoration of such defects to protect the remaining tooth structure and to increase fracture resistance [20]. However, tooth preparation for a prosthetic crown can be always invasive with an irreversible loss of hard tooth structures [21]. Indirect bonded restorations such as onlays, overlays and endocrowns have been recently introduced as a more conservative treatment option for the restoration of endodontically treated teeth [22,23]. They are bonded to the remaining tooth tissues, and by cusp coverage, it can improve stress distribution and minimize the risk of cusp deflection and tooth fracture [24–26]. Moreover, endocrowns offer monoblock restorations that integrate the core and crown in a single unit using axial walls of the pulp chamber for retention in addition to the retention provided by adhesive cementation [27,28]. The ability of partial coverage restorations to provide a practical option for the indirect restoration of endodontically treated teeth was suggested in previous studies [29,30]. However, their mechanical performance compared to conventional crowns still remains a subject of debate.

Lithium silicate glass ceramics have become gradually popular for the fabrication of monolithic ceramic material; their simplified processing methods and adequate bond strength to resin cements allowed them to be used in various restorative situations [31,32]. However, the relative strength of lithium silicate glass ceramics can be a limitation for these restorations [33,34]. Zirconia-reinforced lithium silicate have been introduced with 10 wt% zirconia in their glassy matrix to combine both the aesthetic properties of glass ceramic with the characteristic strength of zirconia ceramics [35,36]. Moreover, advanced lithium disilicate has been recently introduced containing virgilite crystals to enhance the toughness of the material (CEREC Tessera; Dentsply Sirona, Charlotte, NC, USA) [37]. Virgilite crystals are embedded in a zirconia glass matrix along with the lithium disilicate crystals [38]. Although the manufacturer claims improved mechanical properties of CEREC Tessera restorations, limited independent data are available.

The mechanical performance of endodontically treated teeth after indirect restoration can be affected by several factors, including abutment condition, preparation design, and the material of the indirect restoration [39,40]. The aim of this study was to evaluate the effect of margin location (cervical margin relocation, or not) and material (advanced lithium disilicate and zirconia reinforced lithium silicate) of crown, endocrown, and onlay restorations on the fracture resistance of endodontically treated teeth.

2. Materials and Methods

This study was approved by the Local Research Ethics Committee, Faculty of Dentistry, Mansoura University (Code: M03050422). The sample size was calculated based on G*Power V 3.0.10, sample size = 10/group (α error = 0.05, Power = 80.0% and effect size = 1.4).

A total of 120 sound human maxillary molars with comparable shape and dimensions that had been recently extracted for periodontal reasons were selected for the study. All extracted molars were obtained from consenting young adult patients aged 18–40 regardless of sex. Respectively, all extracted teeth were immediately preserved in a sterile saline solution and then inspected under magnification (×20) to exclude any teeth with cracks or caries prior to disinfection in 0.53% sodium hypochlorite solution for one week [41,42]. For periodontal ligament simulation, an even layer of 0.3 mm light-body impression material (KromopanSil; Lascod, Fiorentino, Italy) was applied around selected teeth roots by using a transitional wax technique [43]. Each specimen was embedded along their long axes in an acrylic resin block 3 mm below CEJ and then mounted in a guiding laboratory milling unit

(BF 2; Bredent, Senden, Germany) [44]. A total of 120 MOD cavities were prepared under water cooling using diamond burs (SF-12; Mani Inc., Tokyo, Japan) with 5 mm isthmus width, and the mesial cervical margins were located 2 mm below the CEJ, 1 mm above the CEJ distally (Figure 1). Measurement were taken and markings were made before preparation to maintain preparation standardization [11]. Materials used in this study are listed in Table 1.

(**a**) (**b**)

Figure 1. (**a**) MOD cavity dimensions; (**b**) specimen mounting in a guiding laboratory milling unit.

Table 1. Materials used in the study.

Material	Brand Name	Composition	Manufacturer	Lot Number
Advanced lithium disilicate glass ceramic	CEREC Tessera	90% $Li_2Si_2O_5$, 5% Li_3PO_4, 5% $Li_{0.5}Al_{0.5}Si_{2.5}O_6$	Dentsply Sirona, USA	16013947
Zirconia-reinforced lithium silicate glass ceramic	Celtra Press	58% SiO_2, 18.5% Li_2O, 10.1% ZrO_2, 5% P_2O_5, 1.9% Al_2O_3, 2% CeO_2, 1% Tb_4O_7	Dentsply Sirona, USA	16003549
Self-adhesive, self-curing composite resin cement	Multilink Speed	Dimethacrylates, ytterbium trifluoride, co-polymer, glass filler (base only), silicon dioxide, adhesive monomer, initiators, stabilizers and pigments	Ivoclar Vivadent, Liechtenstein	Z02THB
Light-curing nano-hybrid composite resin	Tetric N- Ceram	BisGMA, Bis-EMA, TEGDMA, barium glass, ytterbium difluoride	Ivoclar Vivadent, Liechtenstein	Z016VJ
Light-curing nano-hybrid Flowable composite resin	Tetric N-Flow	UDMA, bis-GMA, TEGDMA	Ivoclar Vivadent, Liechtenstein	ZL039J
Ceramic etchant	Bisco porcelain etchant	9.5% Buffered hydrofluoric acid gel	Bisco Inc., USA	2100008544
Pre-hydrolyzed silane primer	Bisco porcelain primer	3-propyl-2-Methyl-2-Propenoic Acid, ethanol, acetone	Bisco Inc., USA	2200005217
Tooth etchant	N-Etch Etching Gel	37% phosphoric acid, thickeners and pigments	Ivoclar Vivadent, Liechtenstein	Z03H0Y
Single-component light-curing adhesive	Tetric N-bond universal	Ethanol, phosphonic acid acrylate, Bis-GMA, HEMA, UDMA, diphenyl (2,4,6-trimethylbenzoyl) phosphine oxide	Ivoclar Vivadent, Liechtenstein	Z03WDZ

Following access cavity preparation, root canal treatment was performed in all specimens using rotary instruments (Race; FKG, La Chaux-de-Fonds, Switzerland) up to an apical size of ISO 30. The root canals were filled using laterally condensed gutta-percha

(Meta Biomed, Cheongju-si, Korea) with a resin sealer (Adseal; Meta Biomed, Korea). A thin layer of flowable composite resin (Tetric N-Flow; Ivoclar Vivadent, Schaan, Liechtenstein) was applied as a barrier to the base of the pulp chamber [13]. Then, all specimens were randomly assigned to 6 experimental groups (n = 20), according to the margin location of the crown, endocrown, and onlay restorations (Figure 2). In cervical margin relocation groups, the mesial boxes were elevated up to the level of 1 mm above CEJ with two layers of a nano-hybrid composite (Tetric N-Ceram; Ivoclar Vivadent, Liechtenstein) according to the manufacturer's instructions [10]. Then, 37% phosphoric acid gel (N-Etch; Ivoclar Vivadent, Liechtenstein) was used to itch enamel for 30 s and dentine for 10 s before water rinsing and air drying. A thin coat of universal adhesive (Tetric N-bond universal; Ivoclar Vivadent, Liechtenstein) was then applied, air thinned and light-cured for 10 s using a light-emitting diode (LED) curing light (Elipar DeepCure-S; 3M ESPE, Paul, MN, USA).

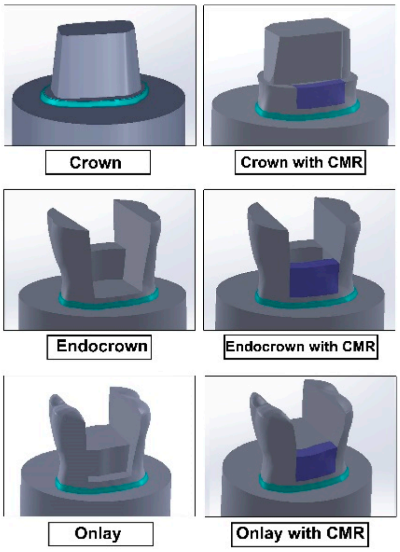


Figure 2. Different margin location and preparation types of the indirect restorations; CMR: cervical margin relocation.

Endocrown preparations received an occlusal reduction of 2 mm using a diamond disc (Transflex-T; Bredent, Germany) to achieve 90° margins [29]. While for the onlay preparations, endodontic access cavities were sealed with composite resin before performing an occlusal reduction of 2 mm using tapered diamond burs (TR-12; Mani Inc., Japan). Pulpal and internal axial walls were prepared with 6° to 8° divergence [41]. For crown preparations, the rest of the MOD cavities were filled with composite resin in 2 mm increments following the manufacturer's instructions before occlusal reduction (1.5 mm) and axial reduction (1 mm) with diamond-tapered burs (TF-12; Mani Inc., Japan) to produce a 1 mm shoulder finish line with 6° to 8° axial convergence [45,46]. The finish lines were located at the CEJ level in cervical margin relocation crown groups and 2.5 mm below the CEJ level in crown groups without cervical margin relocation.

All specimens were then scanned with an optical intra oral scanner (CEREC Omnicam; Dentsply Sirona, USA), and advanced lithium disilicate restorations (CEREC Tessera; Dentsply Sirona, USA) along with wax patterns for zirconia-reinforced lithium silicate restorations (Celtra Press; Dentsply Sirona, USA) were fabricated using a CAD/CAM workflow (CEREC InLab MC X5 System; Dentsply Sirona, USA). For Celtra Press restorations, all wax patterns were dry milled, sprued, and invested. The restorations were then pressed following the manufacturer's instructions using a press furnace (Multimate Cube Press; Dentsply Sirona, USA) before glaze firing. CEREC Tessera restorations were wet milled, then glazed and fired according to the manufacturer's instructions.

Before bonding, the intaglio surface of all restorations was etched with 9.5% hydrofluoric acid (porcelain etchant; Bisco, Schaumburg, IL, USA) before being rinsed for 60 s followed by air drying for 20 s. A silane coupling agent (porcelain primer; Bisco, USA) was applied to the etched surface and left on for 30 s before air drying. The teeth were treated with 37% phosphoric acid to etch enamel and dentine, which was followed by universal adhesive agent application. The restorations were bonded with a self-curing resin cement (Multilink Speed; Ivoclar Vivadent, Liechtenstein) under pressure until complete curing.

The cemented specimens were exposed to 10,000 thermal cycles followed by 240,000 cycles of mechanical loading to simulate one year of clinical service [42,43]. A thermo-cycler apparatus (thermocycler 1100; SD Mechatronik, Feldkirchen-Westerham, Germany) was used for thermal aging altering the temperature between 5 and 55 °C with a dwell time of 30 s and 5 s transfer time, which was followed by mechanical loading using a chewing simulator machine (Chewing Simulator CS-4; SD Mechatronik, Germany) with 1.6 Hz frequency to replicate a unidirectional intermittent axial load of 50 N applied in the center of the occlusal surface parallel to the long axis of the tooth.

Following the aging procedures, all specimens were subjected to load-to-fracture test using a universal testing machine (3345; Instron, Norwood, MA, USA) to determine the fracture resistance (N) and fracture pattern of each specimen. A compressive load with a 6 mm diameter steel sphere was applied perpendicular to the central fossa with a crosshead speed of 0.5 mm/min [13]. A stereomicroscope (SZ61; Olympus, Tokyo, Japan) was used for the detailed evaluation of fractured specimens under magnification [43]. Failure patterns were classified according to fracture prognosis as described in Table 2 [29]. Representative fractured specimens were analyzed using a scanning electron microscope (SEM) (JSM-6510, JEOL, Tokyo, Japan). The specimens were sputter-coated with a 30 nm thick uniform layer of gold for 180 s at 40 mA using SPI Sputter Coating (SPI supplies, West Chester, PA, USA) [42].

Table 2. Classification of failure patterns.

Type	Failure Pattern	Description
I	Restorable	Fracture within the restoration
II	Restorable	Fracture of the restoration and tooth above the CEJ
III	Unrestorable (catastrophic)	Fracture of the restoration and tooth below the CEJ

CEJ: cemento-enamel junction.

Data analysis was conducted with statistical software IBM SPSS (version 22, IBM Co., Drive Armonk, NY, USA). Data were described using mean ± standard deviation for normally distributed data, and a Kolmogorov–Smirnov test (sig = 0.20) was used to confirm normality, while Levene's test (sig = 0.54) was used to validate variances in the homogeneity. The significance of difference was performed using different categories of tests: three-way ANOVA, one-way ANOVA, and post hoc Tukey test. The significance of the obtained results was judged at the ($\leq$0.05) level.

3. Results

Mean fracture strength results are presented in Table 3 and Figure 3. The mean fracture resistance was significantly higher among crowns followed by endocrowns and then onlays for all fracture resistance readings except for CEREC Tessera restoration without cervical margin relocation, where the differences were insignificant. Considering the margin location, cervical margin relocation significantly decreased the fracture resistance values in all test groups (Table 4). A statistically significant higher mean fracture resistance was identified among Celtra Press compared with CEREC Tessera in crown restorations with and without cervical margin relocation. However, no statistically significant difference was found between both materials in endocrown and onlay preparations with or without cervical margin relocation (Table 4).

Table 3. Mean ± standard deviation of fracture resistance (N).

Material	Margin Location	Design	Fracture Resistance Mean ± SD	Test of Significance
Cerec Tessera	Without CMR	Crown Endocrown Onlay	1805.39 ± 267.64 1763.44 ± 212.04 1703.18 ± 193.43	F = 0.514 $p = 0.604$
	With CMR	Crown Endocrown Onlay	1530.08 ± 243.12 ^{b} 1340.11 ± 216.74 ^{a} 1057.19 ± 203.42 ^{ab}	F = 8.99 $p = 0.001$ *
Celtra Press	Without CMR	Crown Endocrown Onlay	2136.57 ± 216.41 ^{ab} 1584.28 ± 205.41 ^{a} 1566.19 ± 236.38 ^{b}	F = 21.76 $p = 0.001$ *
	With CMR	Crown Endocrown Onlay	1866.24 ± 219.81 ^{bc} 1356.90 ± 225.99 ^{ab} 950.47 ± 208.12 ^{ac}	F = 44.26 $p = 0.001$ *

F: one-way ANOVA test; similar superscripted letters in same column denote significant difference between studied groups; * statistically significant; CMR: cervical margin relocation.

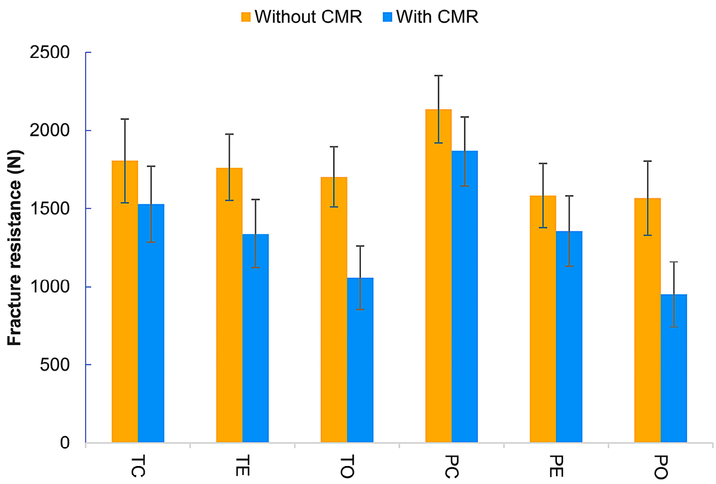


Figure 3. Mean ± standard deviation of fracture resistance (N); T: CEREC Tessera; P: Celtra Press; C: crown; E: endocrown; O: onlay; CMR: cervical margin relocation.

Table 4. Comparison of mean fracture resistance values between different margin locations and restoration materials.

Restoration Type	Without CMR		With CMR	
	CEREC Tessera	Celtra Press	CEREC Tessera	Celtra Press
Crown	1805.38 ± 267.64 ^{A}	2136.57 ± 216.41 ^{B}	1530.08 ± 243.01 ^{C}	1866.24 ± 219.81 ^{A}
Endocrown	1763.44 ± 212.04 ^{A}	1584.28 ± 205.41 ^{A}	1340.11 ± 216.74 ^{B}	1356.90 ± 225.99 ^{B}
Onlay	1703.18 ± 193.43 ^{A}	1566.19 ± 236.38 ^{A}	1057.19 ± 203.42 ^{B}	950.47 ± 208.12 ^{B}

Different superscripted uppercase letters indicate significant differences in rows; Tukey significant difference test ($p < 0.05$); CMR: cervical margin relocation.

According to the three-way ANOVA test shown in Table 5, the fracture resistance of the tested specimens was significantly different depending on the type and margin location of the indirect restoration ($p = 0.001$). However, the material type had no statistically significant effect on fracture resistance ($p = 0.284$). A combined change in the material and restoration type, along with a combined change in the margin location and restoration type, had a statistically significant effect on fracture resistance ($p < 0.001$). A combined change in the material and margin location ($p = 0.343$), along with combinations of all three variables, had no statistically significant effect on fracture resistance ($p = 0.580$).

Table 5. Three-way ANOVA for margin location, restoration type, and material.

Source	Sum of Squares	*df*	Mean Square	F	*p*
Margin location	5,035,063.352	1	5,035,063.352	102.569	0.001 *
Restoration type	5,426,067.054	2	2,713,033.527	55.267	0.001 *
Material	56,881.263	1	56,881.263	1.159	0.284
Margin location × restoration type	747,598.643	2	373,799.321	7.615	0.001 *
Margin location × material	44,541.353	1	44,541.353	0.907	0.343
Restoration type × material	1,270,879.707	2	635,439.854	12.944	0.001 *
Margin location × restoration type × material	53,808.213	2	26,904.107	0.548	0.580
Error	5,301,687.200	108	49,089.696		
Total	3.081×10^8	120			
Corrected Total	1.794×10^7	119			

* statistically significant.

Fractured specimens mostly presented unrestorable fracture patterns in all test groups, which extended to the root below the CEJ (Figure 4). Vertical fracture patterns splitting the restoration were predominantly seen in endocrown and onlay groups, while more destructive fracture patterns were seen in crown restorations (Figures 5 and S1). The SEM images demonstrated the different fracture patterns where cervical extending cracks were mainly seen in endocrowns and onlays; on the other hand, cracks extending from occlusal load contact were seen in crown restorations (Figure 6).

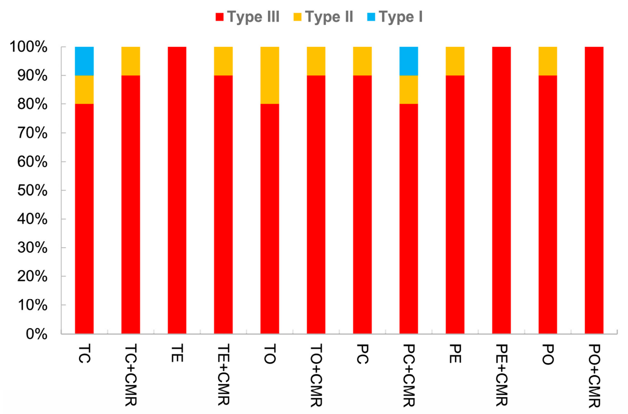
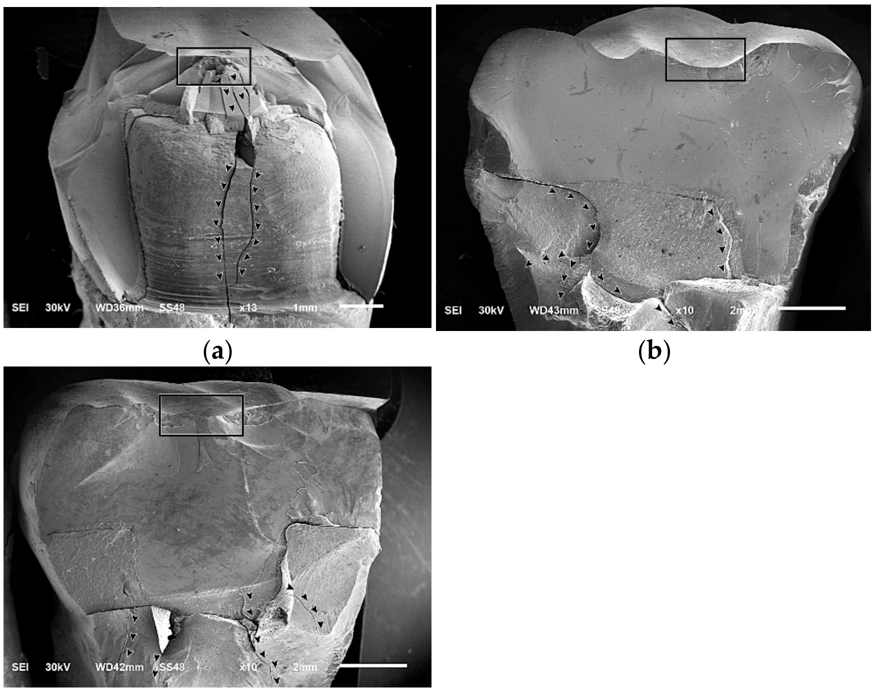


Figure 4. Percentage of failure types in each studied group; T: CEREC Tessera; P: Celtra Press; C: crown; E: endocrown; O: onlay; CMR: cervical margin relocation.

(**a**) (**b**)

Figure 5. Representative images of fractured specimens with unrestorable failure pattern: (**a**) CEREC Tessera onlay specimen; (**b**) Celtra Press crown specimen with cervical margin relocation.



(**a**) (**b**) (**c**)

Figure 6. Representative scanning electron microscopic images of fractured specimens; (**a**) CEREC Tessera crown specimen with CMR showing cracks extending from occlusal load contact; (**b**) Celtra Press onlay specimen showing cervical extending cracks; (**c**) CEREC Tessera endocrown specimen with CMR showing cervical extending cracks; CMR: cervical margin relocation.

4. Discussion

The objective of this in vitro study was to investigate how the margin location and the material of the crown, endocrown, and onlay restorations influenced the fracture resistance of endodontically treated maxillary molars. It was demonstrated that the margin location (cervical margin relocation, or not) significantly affected the fracture resistance of the endodontically treated molars. However, the material of the indirect restoration had no significant impact on the fracture resistance. Moreover, the type of the indirect restoration significantly affected the fracture resistance of the endodontically treated molars, while the combination of margin location, restoration material and type had no significant impact of fracture resistance.

The mean fracture resistance values in the present study ranged between 950 and 2163 N; these values were comparable to the values obtained by Ilgenstein et al. [10] (1083.0–1995.8 N), and Bresser et al. [11] (1194–1986 N). However, these values were higher than those obtained by Zhang et al. [13] (1083.6–1446.9 N), who used premolars as abutments for their study. Higher fracture resistance values were reported by Grubbs et al. [12] (1700–2029 N); however, specimens in their study did not receive endodontic treatment. Specimens in both the studies of Robaian et al. [45] and Alahmari et al. [46] received full contour monolithic crowns with no endodontic treatment and recorded fracture resistance values of (1671–2203 N), and (1891–2494 N), respectively.

Previous studies have not found a negative impact of cervical margin relocation on the fracture resistance of posterior teeth when used in combination with indirect restorations [10–12]. However, cervical margin relocation in the current study significantly affected the fracture resistance of the endodontically treated maxillary molars. These results are in accordance with the results of Robaian et al. [45] and Alahmari et al. [46], where cervical margin relocation had a significant impact on the fracture resistance of the indirectly restored teeth. Extension of the indirect restorations margins to sound tooth structures can explain the higher fracture resistance values obtained by specimens with no cervical margin relocation [15,19]. Despite the negative effect of cervical margin relocation on fracture resistance, mean fracture resistance values after cervical margin relocation ranged between 950 and 1866 N, which exceeded the maximum voluntary axial bite forces that can be found in the oral cavity (480–788 N) [47]. These results can show that when cervical margin relocation is indicated, it can be a practical solution for the restoration of deep cervical defects in combination with indirect restorations.

The selection of suitable restorative material following root canal treatment is essential to provide sufficient strength for both prosthetic restoration and the remaining tooth structure [14]. The current study compared the fracture resistance of newly introduced advanced lithium disilicate to more traditional zirconia reinforced lithium silicate with different types of indirect restoration. For partial coverage restoration, there was no significant difference in facture resistance values between both materials. This is in line with previous studies comparing zirconia-reinforced lithium silicate to conventional lithium disilicate ceramics, where lithium disilicate restorations showed comparable fracture resistance values to zirconia-reinforced lithium silicate [28,30]. However, when it comes to full coverage restorations, the fracture resistance of zirconia-reinforced lithium silicate was significantly higher than advanced lithium disilicate restoration. This may be explained by the addition of 10% zirconia to the lithium silicate material composition, which can add to the strength of the material. This is also in line with previous studies that reported a better performance of zirconia-reinforced lithium silicate with full crown restorations compared to lithium disilicate ceramics [34,35].

Comparing different types of indirect restoration following root canal treatment can be useful to determine the best post-endodontic restorative option [41]. In the current study, full coverage crowns still represented the best treatment option with and without cervical margin relocation. They showed higher fracture resistance values compared to the less invasive partial coverage preparations. These results agree with the study by Frankenberger et al. [18] where minimally invasive preparations were less successful in the rehabilitation of endodontically treated teeth compared to more invasive ones. Jurado et al. [20] also found a higher fracture resistance of full crowns compared to partial coverage restorations. The wider distribution of stresses over the full coverage crown restoration can explain their better mechanical performance compared to partial coverage restorations, where stresses can be focused on smaller areas. Both types of partial coverage restorations showed comparable fracture resistance results before cervical margin relocation. However, after cervical margin relocation, endocrowns performed significantly better than onlays with higher fracture resistance values. This is in line with the study by Zhang et al. [13] where endocrown restorations in combination with cervical margin relocation improved the fracture resistance of endodontically treated teeth.

Most of the tested specimens showed unrestorable or catastrophic fracture patterns that extended to the root below CEJ. Similarly high percentages of unrestorable fractures were observed in the previous in vitro studies testing cervical margin relocation in combination with indirect restorations [11,12,45,46]. This can be explained by the extension of the restoration below the CEJ, transmitting forces toward weak cervical margins. The current study has possible limitations that include the use of only two types of materials and the vertical load application that does not resemble lateral forces, which can be found in the oral cavity. Another possible limitation is that the specimens were subjected to aging protocol that resembled only one year of clinical service. Future studies with more ceramic materials, lateral load application, and prolonged aging protocols are recommended. Despite the inherent limitations of the current study, the results can be useful for the development of further studies.

5. Conclusions

Based on the findings of the present study, the following conclusions can be drawn:

(1) Margin location of the indirect restorations significantly affected the fracture resistance of the endodontically treated molars with an adverse effect of cervical margin relocation on the fracture resistance values in all study groups.
(2) The material of the indirect restorations had no significant impact on the fracture resistance.
(3) Crown restorations represented the best restorative option following endodontic treatment in terms of fracture resistance.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/prosthesis6050080/s1, Figure S1: Representative images of fractured specimens with different failure patterns.

Author Contributions: Conceptualization, M.D., W.A.-Z. and A.S.; software, W.A.-Z.; methodology, M.D., W.A.-Z., M.O. and A.S.; formal analysis, W.A.-Z. and A.S.; investigation, M.D., W.A.-Z. and A.S.; resources, M.D., W.A.-Z., M.O. and A.S.; data curation, W.A.-Z.; writing—original draft preparation, M.D., M.O. and W.A.-Z.; writing—review and editing, M.D., W.A.-Z., M.O. and A.S.; supervision, W.A.-Z., M.O. and A.S.; project administration, A.S.; funding acquisition, M.D., W.A.-Z., M.O. and A.S. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Local Research Ethics Committee, Faculty of Dentistry, Mansoura University (Code: M03050422). This study did not involve humans or animals.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

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