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FRACTURE RESISTANCE OF RESTORATIONS WITH FIBER-REINFORCED COMPOSITES. SYSTEMATIC ANALYSIS

Fernando Pessoa University

Faculty of Health Sciences

Porto, 2023

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Paper presented to Fernando Pessoa University as part
of the requirements for obtaining the degree of
Master of Dental Medicine

Signature: ___________________________________

ABSTRACT:

<u>Aims</u>: This study aimed to evaluate and compare the fracture resistance values of composed/complex fiber-reinforced composite restorations, in posterior teeth, with those of healthy teeth, or of non-fiber-reinforced composites restorations or, of unrestored cavity preparations by means of an in vitro outputs systematic quantitative and qualitative analysis.

<u>Methodology</u>: Methodic search was performed using PubMed, Web of Science and Google Scholar from 15th may to 12th June 2023. Only in vitro studies published as articles in English idiom in the last 10 years, and that evaluate/compared the fracture resistance values of human posterior teeth with extensive fiber-reinforced composite restorations, with those of healthy teeth, or of non-fiber-reinforced composites restorations or, of unrestored cavity preparations were included. This study was registered (425509) in PROSPERO database and followed the PRISMA guidelines. The risk of bias assessed by The QUIN tool. The fracture resistance median values, in Newton (N), were calculated for all, experimental and control groups with a 95% confidence interval. For pairwise comparation nonparametric tests (<0.05) were applied.

<u>Results</u>: From 932 articles obtained, only 24 publications met the inclusion criteria; 23 had moderate and one high risk of bias. Overall fracture resistance of experimental group median value was of 976.0 N and differ from all control groups. Pairwise comparison revealed that experimental group showed lower values of fracture when compared with healthy teeth (1459.9; p=0.048) but higher than those of two control groups, composite non-fiber-reinforced restoration (771.0 N; p=0.008) and cavity preparation without restoration (386.6 N; p<0.001).

<u>Conclusion</u>: In vitro systematic outputs evidenced that glass and/or polyethylene fibers can improve composite restorations fracture resistance values.

KEY WORDS: fiber-reinforced composites; glass fibers; polyethylene fibers; composite resin; fracture resistance; in vitro.

RESUMO

<u>Objetivos</u>: Este estudo pretendeu avaliar e comparar os valores de resistência à fratura de dentes posteriores com restaurações compostas/complexas com compósitos reforçados por fibras em comparação com dentes hígidos, ou restaurações com compósitos não reforçados por fibras ou com preparos cavitários não restaurados, através uma análise sistemática quantitativa e qualitativa de resultados de estudos *in vitro*.

<u>Metodologia</u>: Uma pesquisa foi realizada na *PubMed, Web of Science* e *Google Scholar* entre 15 de maio a 12 de junho de 2023. Foram incluídos estudos *in vitro* publicados em língua inglesa, nos últimos 10 anos, que avaliaram/compararam os valores de resistência à fratura de dentes posteriores humanos com restaurações extensas com compósitos reforçados com fibras, com valores obtidos em dentes, hígidos, com restaurações com compósitos não reforçados por fibras ou, com preparos cavitários não restaurados. Este estudo foi registado (425509) na base de dados PROSPERO e seguiu as diretrizes PRISMA. Para análise do risco de viés dos estudos recorreu-se ao *The QUIN*. Os valores medianos da resistência à fratura, em Newton (N), foram calculados para todos os grupos, experimental e controlos com um intervalo de confiança de 95%. Para comparação de resultados foram aplicados testes não paramétricos ($<0,05$).

<u>Resultados</u>: De 932 possíveis artigos obtidos, apenas 24 publicações cumpriram os critérios de inclusão, dos quais 23 revelaram risco de viés moderado e um alto. O valor mediano da resistência à fratura global do grupo experimental foi de 976.0 N e diferiu dos obtidos nos grupos controlo. A comparação entre os grupos revelou que o grupo experimental apresentou valores mais baixos de resistência à fratura quando comparado com os obtidos em dentes hígidos (1459.9, p=0.048), mas mais elevados do que os dos restantes dois grupos de controlo, restauração de compósito não reforçada com fibra (771.0 N, p=0.008) e preparação cavitaria sem restauração (386.6 N, $p<0.001$).

<u>Conclusão</u>: Os resultados sistemáticos de estudos *in vitro* evidenciaram que fibras de vidro e/ou polietileno podem melhorar os valores de resistência à fratura de dentes posteriores com restaurações com compósitos.

PALAVRAS-CHAVE: compósitos reforçados com fibras, fibras de vidro, fibras de polietileno, resina composta, resistência à fratura, *in vitro*.

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ABBREVIATIONS

PROSPERO - International Prospective Register of Systematic Reviews

PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyses

N - Newton

PICO - Population, intervention, control, outcome

MESH - Medical Subject Headings

MOD - Késio-oclusal-distal

MO - Késio-oclusal

QUIN - Quality Assessment Tool For In Vitro Studies

°C: Degrees Centigrade or Celsius

mm/min: millimeter/minute

I - INTRODUCTION

The dental tissues loss affects the biomechanical behavior of the tooth and inherently, the remaining teeth. Extensive cavity preparations, restorative procedures and endodontic treatment can result in increased structural fragility of the tooth, which can lead to fracture of crowns, roots or even loss of the dental organ (Gaeta et alii., 2021). To minimize wear and dental hard tissues loss, restorative procedures are mandatory. The selection of the restorative material will depend on many conditions, such us the remaining tooth structure and the functional assumptions to be returned to the organ, in addition to aesthetic considerations and functional and biological re-anatomization of structures (Vetromilla et alii., 2020).

Composed and complex cavity preparations of posterior teeth, due to proximal wall involvement exhibit higher load concentration, greater cusp deflection and, may have, additional stress generated by polymerization shrinkage of polymeric materials. Due to their own cavity configuration, the number of walls and the marginal ridge loss, the extent of the occlusal isthmus and the depth of the preparation, the involved tooth becomes more susceptible to fracture (Soares et alii., 2013).

Composite resins remains the material of first choice for direct restorations of posterior teeth by their mechanical properties, aesthetics, and clinical performance (Ferracane and Lawson, 2021). However, and due to some limitations, adhesives and composites may compromise, over time, the biological, the functional and the clinical success of posterior teeth restorations, particularly regarding the detection of secondary caries lesions and fracture of restorations and/or teeth (Da Rosa Rodolpho et alii., 2022). In turn, restorations clinical, biological and functional failures, may occur due to inadequate fracture resistance of the polymeric material, or poor resistance to crack propagation when the restoration is exposed to functional and para-functional mechanical loads (Lassila et alii., 2018; Chai, 2023).

Consequently, the tooth-strengthening effect by resin composites is still debated in the literature, especially when those medical devices are directly applied for the restoration of extensive tooth cavities in some high compressive and tensile loads of intra-oral locations (Fráter et alii., 2021). In an attempt to improve the mechanical strength and durability of resin composite restorations in posterior teeth, several mechanisms have been proposed, including the use of both, fiber-reinforcement devices, applied directly and internally in cavity preparations, and polymeric materials, in order to increase the biomechanical behavior of this set (Scribante, Vallittu and Özcan, 2018).

The reinforcement by different types of fibers is not an innovative concept, it has been the basis of engineering and architecture in the construction of devices with high strength and fracture resistance. This resource, for dental applications, has been discussed in the literature since the early 1960s, when they were first proposed to reinforce acrylic denture bases (Vallittu, 2015).

Fiber-based devices can be used as a potential internal reinforcement of extensive direct resin composite restorations of vital or endodontically treated teeth, of single crowns or fixed partial dentures and of the direct root canal retentions. As external reinforcements are also a resource for tooth splinting in order to give some support to teeth due to some periodontal or orthodontic conditions (Tayab, Shetty and Kayalvizhi, 2015).

Reinforcement fibers structurally presents three different components, the matrix or continuous phase, the fibers or dispersed phase, and the matrix/fiber interface. The reinforcement effect is based on a load-stress transfer from the polymer matrix to the fibers acting as a stress dissipator, internally strengthening the compromised tooth structure and serving as a fracture prevention layer, when a functional or para-functional load is applied (Scribante et alii., 2018).

The effectiveness of fiber reinforcement will depend on many variables such as the type of resin composite selected, the number of fibers in the resin matrix, the type, length, form, orientation (unidirectional, bidirectional, multidirectional) of the respective fibers, the adhesion to the polymer matrix and, the resin impregnation of the fibers device (Vallittu, 2015).

Commonly, polyethylene and fiberglass are the most popular type used with direct composite restorations. The fiberglass is an inorganic material that varies according to its composition (A, C, D, E, R, and S-glass), presenting adequate aesthetics, high tensile strength, low thermal conductivity, high corrosion resistance and adequate surface chemistry, that allows its adhesion to the resin-based materials. However, it presents some limitations such as, brittleness and low wear resistance (Rana et alii., 2021). Polyethylene fibers are constituted of aligned polymer chains with low density modulus, which enables higher impact strength. Ultra-high modulus polyethylene fibers architecture allows uniform force distribution in more than one direction, with enhanced mechanical properties, high impact strength, excellent chemical resistance, low moisture absorption, vibration dampening ability and, low coefficient of friction (Miao et alii., 2016).

Reinforcement fibers associated with composites can potentially counteract the adverse effects of resins polymerization shrinkage and the consequent stress forwarded to the composites and the remaining dental hard tissues. Simultaneously, can promote improvement to the physical properties of composite restorations (Aggarwal et alii., 2018).

Considering the clinical application, this biomimetic approach may represent a less invasive and more conservative restorative option, when compared to some indirect polymers and restorative techniques, more economic and time efficient, and a promising technique to prevent the fracture of extensive restorations in posterior teeth (Deliperi, Alleman and Rudo, 2017).

Several studies, mainly in vitro, have been done to evaluate the fracture resistance of fiber-reinforced resin composite restorations, but the results are still contradictory and controverse. Some suggest that the use of fibers increase the fracture resistance of composite restorations while others show similar outcomes by using, or not, fibers with the restorative polymeric materials (Mangoush et alii., 2017; Mangoush et alii., 2021; Jakab et alii., 2022; Albar and Khayat, 2023).

Thus, it becomes important to analyse the mechanical behavior of glass and/or polyethylene fibers regarding the reinforcement, or not, of resin composite restorations. Therefore, this systematic study aimed to evaluate and compare the fracture resistance values of human posterior teeth with extensive fiber-reinforced composite restorations, with those of healthy teeth, or of non-fiber-reinforced composite restorations or, of unrestored cavity preparations, by means of a qualitative and quantitative analysis of in vitro studies and their outputs.

For those purposes, the following hypotheses were tested:
H_0 - Fracture resistance value of posterior teeth with fiber-reinforced composite restorations do not differ from those of healthy teeth, or of non-fiber-reinforced composites restorations or of unrestored cavity preparations.

H_1 - Fracture resistance value of posterior teeth with fiber-reinforced composite restorations differs from those of healthy teeth, or of non-fiber-reinforced composites restorations or of unrestored cavity preparations.

II - MATERIAL and METHODS

The systematic review and study protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) database under code CRD42023425509 (**Annex I**), and we followed the recommendations of the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) (Page et alii., 2021; Equator network, 2023). The search question applied to this work was: *Does the restoring of posterior teeth with fiber-reinforced composites shows fracture resistance values similar to those of healthy posterior teeth or, of non-fiber-reinforced composite restorations, or of unrestored extensive cavity preparations?*

1 – Search Strategy and Data Collection Process

A methodic search was performed by two team members (L.E and L.P.S) using MEDLINE/PubMed, Web of Science and Google Scholar up to 12th June 2023. The search strategy included 4 main Medical Subjects Headings (MeSH), “fiberglass”, “polyethylene”, “composite resins”, “in vitro test”. The following terms, from tree structures, “fiber-reinforced”, “composite”, “glass fibers”, ”polyethylene fibers”, “composite resin”, “fracture resistance”, “in vitro” were join by Boolean operators (“OR” and “AND”), according to the relevance of the search question. The controlled vocabulary, MeSH terms, and keywords from tree structures of the search strategy are presented in **Table 1**. Search terms were included in the title and/or in the abstract and were appropriately modified for each database.

Table 1 - Search strategy used in each electronic database.

PubMed*		
# 1 (Molar [MeSH Terms])) OR (Bicuspid [MeSH Terms])) OR (Molars [Title/Abstract])) OR (premolar [Title/Abstract])) OR (Posterior teeth [Title/Abstract]))	**# 2** (Fiber reinforcement [Title/Abstract]) OR (Fiber-reinforced composite dentistry [Title/Abstract]) OR (Fiber-reinforced restoration [Title/Abstract]) OR (Fiber-reinforced composite resin [Title/Abstract])) OR (Fiber cavity reinforcement [Title/Abstract])) OR (Polyethylene fiber-reinforced [Title/Abstract])) OR (Polyethylene fiber [Title/Abstract])) OR (Fiber glass [Title/Abstract])) OR (Glass fiber [Title/Abstract])) OR (Glass fiber-reinforced [Title/Abstract])) OR (E-glass Fiber reinforced composite [Title/Abstract])) OR (Short fiber-reinforced [Title/Abstract])) OR (Ribbond [Title/Abstract])) OR (Ribbond fiber [Title/Abstract])) OR (EverStick [Title/Abstract])) OR (EverStick Fiber [Title/Abstract])) OR (EverStick NET [Title/Abstract])) OR (EverStick C&B [Title/Abstract])	**# 3** (Fracture resistance [Title/Abstract]) OR (Fracture strength [Title/Abstract]) OR (Fracture resistance fiber-reinforcement composite [Title/Abstract])
# 1 AND # 2 AND # 3		
Web of Science*		
# 1 topic: Molar* OR Bicuspid* OR Premolar* OR Posterior teeth* # 1 AND # 2 AND # 3	**# 2 topic**: Fiber reinforcement* OR Fiber-reinforced composite* OR Fiber-reinforced restoration* OR Fiber-reinforced composite resin* OR Fiber cavity reinforcement* OR Polyethylene fiber* OR Fiber glass* OR Glass fiber*	**# 3 topic**: Fracture resistance* OR Fracture strength* OR fracture resistance fiber-reinforced composite*
Google Scholar*		
# 1 In tittle: (Molar OR Premolar OR Posterior teeth) # 1 AND # 2 AND # 3	**# 2 In tittle**: (Fiber reinforcement OR Fiber-reinforced composite OR Fiber-reinforced restoration OR Fiber cavity reinforcement OR Polyethylene fiber OR Fiber glass OR Ribbond)	**# 3 In tittle**: (Fracture resistance OR Fracture strength)

2 - Inclusion criteria, exclusion criteria and eligibility

Only in vitro studies involving human permanent posterior teeth, that assessed and compared the fracture resistance values of extensive, composed/complex, fiber-reinforced composite restorations with those of healthy teeth, or of non-fiber-reinforced composites restorations or, of unrestored cavity preparations, were included. Also, only articles written in English language and published in the last 10 years (2013 up to 12th June 2023) were scrutinized for this review.

To assess the fracture resistance values, in Newton (N), of vitro outputs, studies were collected and analyzed according to the PICO strategy: **Population:** human posterior teeth after exodontic procedure with composed (2 surfaces) or complex (3 surfaces) cavity preparation, with or without root canal treatment; **Intervention:** direct resin composites restorations reinforced with fiberglass and/or polyethylene fibers; **Comparison:** healthy teeth, non-fibers-reinforced composite restorations and unrestored cavity preparations in extracted posterior teeth, all after exodontic procedures; **Outcome:** fracture resistance values (N).

Other types of published research than those considered in inclusion criteria such us, those with distinct methodology of in vitro trials, that assessed other fiber-reinforced restorations mechanical properties, with incomplete abstracts or full text, that involved non-human teeth or other cavity preparations prototypes, with absence of control group in the study protocol and with experimental groups that assessed root canal retentions were excluded.

2.1 - Study screening and selection

Articles identified using the search terms were exported to Mendeley desktop Reference Manager v2.94.0 software to check for duplicates. A first screening of record titles and abstracts was carried out by two independent examiners (L.E and P.M.M.) considering the inclusion and exclusion criteria, the purposes of this research and PICO approach. The remaining studies were assessed for eligibility and qualitative synthesis by full-text screening. An identification number was assigned to each eligible study.

2.2 - Study data

Bibliometric analysis was performed recording the authors and year of publication. The methodology of examination included the aims, materials and methods and outputs of the included studies, as the results, expressed in Newton, of the independent variable, the mean value and standard deviation of fracture resistance. For the qualitative analysis also were collected some variables of the in vitro protocols, such us the control group of the designed study, the type (premolar and/or molar) of posterior teeth involved, the sample dimension (number of teeth tested and controlled), the type of fibers and resin composites used to restore, the technical intervention and devices for fracture resistance test/measurement.

3- Risk of bias of each individual in vitro trial

The risk of bias and quality assessment was performed for each in vitro study using the Quality Assessment Tool for In Vitro Studies (The QUIN) (Sheth et alii., 2022) which consists of 12 criteria with scores for each domain (adequately specified=2 points; inadequately specified=1 point; not specified=0 points; not applicable = excluded criteria). The final score for each study was obtained using the formula: Total score x 100/2 x number of applicable criteria, a value that allows the classification of studies >70%=low risk of bias, 50% to 70%=medium risk of bias, and <50%=high risk of bias.

4- Data synthesis and statistical analysis

Data were analyzed using the statistical software program, IBM SPSS Statistics version 26. The degree of confidence was 95% in all tests (alpha equal to 0.05). For inferential analysis, the sample amplitude and dispersion was analyzed using histograms, complemented by the Kolmogorov-Smirnov test. The central point with the highest number of occurrences, the median, maximum and minimum values and respective quartiles (Q_1-Q_3) were determined. The fracture resistance median values were assessed for the experimental group (fiber-reinforced composite restorations) and for the three control groups (healthy teeth, non-fiber-reinforced composites restorations and unrestored cavity preparations), with a 95% confidence interval. For pairwise comparation of the discrete numerical independent variables, within each group (experimental and controls) and also, between the experimental and each control groups, nonparametric tests (<0.05) were applied.

III - RESULTS

1. Studies selection and flow diagram of in vitro studies

A total of 932 preliminary references were identified by searching the electronic databases (**Figure 2**). After exclusion of duplicates, 730 articles were selected for title evaluation and 151 articles were submitted to abstract reading and discussion. After screening, 25 articles were examined at full-text level. One article was excluded for not meeting the inclusion criteria. Twenty-four in vitro studies met the eligibility criteria and were included in this review for data qualitative and quantitative collection. The selected studies and their main characteristics are summarized in **Table 2**.

Figure 2 - PRISMA flow chart for systematic reviews (Page et alii., 2021; Equator network, 2023).

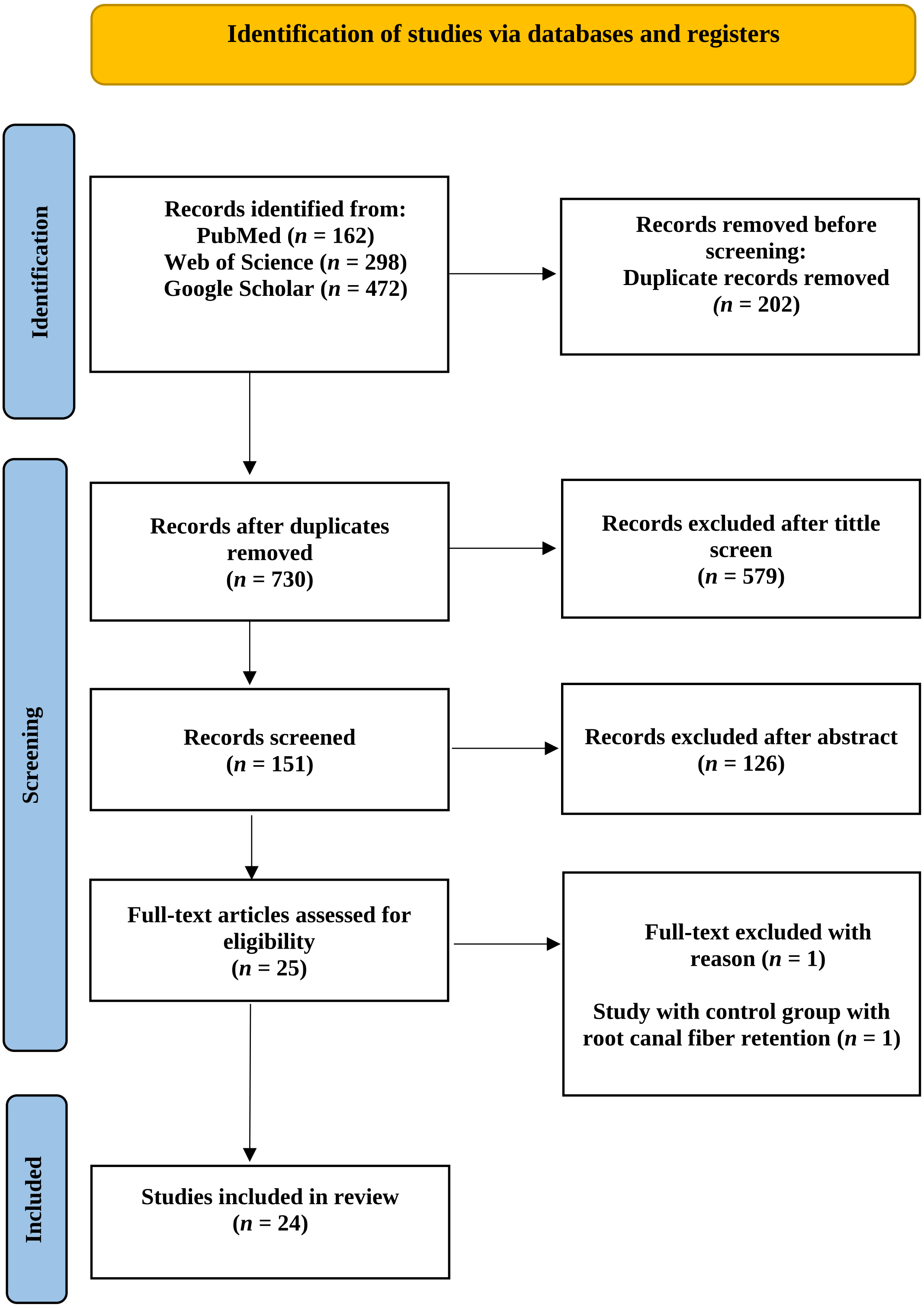

Table 2 - Details of the included in vitro studies (*n*=24).

In Vitro Study (Reference)	Experimental Group		Control Group	Fracture resistance evaluation	Main Conclusion
	Type of fibers	Application technique		Mean (SD)[1] (Newton)	
Agrawal, Shah and Kapoor, 2022	Polyethylene fiber Ribbond® (Ribbond Inc.)	Gingival and pulpal floor; pulpal floor; vertical on gingival and pulpal floor; fiber chips	Non-fiber-reinforcement composite restorations	***Experimental Groups**- G_2**: 1288.8 (186.9); **G_3**: 976 (142.3); **G_4**: 942.3 (151.5); **G_5**: 876.3 (165.8) ***Control Groups** - G_1**: 588.4 (69.6); **G_6**: 833.0 (201.1)	Horizontal orientation of fiber on both pulpal and gingival floor of MOD cavities gives the highest fracture resistance
Albar and Khayat, 2022	Polyethylene fiber Ribbond® (Ribbond Inc.)	Axial wall of the proximal cavity; gingival floor of the proximal cavity; axial wall and pulpal/gingival floor of the proximal cavity	Non-fiber-reinforcement composite restorations	***Experimental Groups** - G_2**: 422.1 (14.9); **G_3**: 409.0 (15.9); **G_4**: 446.2 (12.9) ***Control Group** - G_1**: 390.2 (10.4)	The reinforcement of direct composite resin restorations with polyethylene fibers increased the fracture resistance of the restorations in comparison with non-reinforced restorations
Balkaya et alii., 2022	Polyethylene fiber Ribbond® (Ribbond Inc.)	Buccal; lingual and pulpal walls	Positive control (PC) Unrestored cavity preparation Negative control (NC) Healthy teeth	***Experimental Groups** - G_7**: 601.0 (133.0); **G_8**: 658.0 (116.0) ***Control Groups** - NC**: 952.0 (111.0); **PC**: 219.0 (48.0); **non-fiber-reinforcement composite: G_3**: 440.0 (102.0); **G_4**: 447.0 (101.0); **G_5**: 459.0 (126.0); **G_6**: 464.0 (115.0)	Ribbond in combination with composite resin enhanced the fracture resistance of teeth
Özüdoğru and Tosun, 2022	Polyethylene fiber Ribbond® (Ribbond Inc.)	Buccal and lingual walls and fiber placed on circumferential way	Healthy teeth (HT)	***Experimental Groups** - G_3**: 2602.1 (126.2); **G_4**: 2805.7 (125.9) ***Control Groups**- HT**: 2710.4 (171.2); **non-fiber-reinforcement composite: G_2** : 2312.5 (112.0)	Polyethylene fiber reinforcement did not affect the fracture resistance of composite resin restorations
Bainy et alii., 2021	Fiberglass post Reforpost® (Angelus) Fiberglass Interlig® (Angelus)	Horizontal transfixation on buccal and palatal walls Placed on circumferential way	Positive control (PC) Healthy teeth Negative control (NC) Unrestored cavity preparation	***Experimental Groups** - G_4:** 2256.0 (289.2); **G_5:** 2493.0 (364.0) ***Control Groups** - PC:** 3563.0 (780.7); **NC**: 1001.0 (237.6); **non-fiber-reinforcement composite: G_3**: 1689.0 (280.7)	The fiber glass, regardless of composition, increases the fracture resistance of endodontically treated teeth
Shafiei et alii., 2021	Polyethylene fiber Ribbond® (Ribbond Inc.)	Buccal; lingual and pulpal walls	Positive control (PC) Unrestored cavity preparation Negative control (NC) Healthy teeth	***Experimental Groups** - G_6**: 858.0 (215.0); **G_7**: 529.0 (124.0); **G_8**: 802.0 (201.0) ***Control Groups** - NC**: 1204.0 (252.0); **PC**: 352.0 (143.0); **non-fiber-reinforcement composite: G_3**: 579.0 (114.0); **G_4**: 596.0 (138.0); **G_5**: 624.0 (182.0)	The effect of fiber insertion on fracture resistance depended on the type of composite resin; the highest reinforcing effect was obtained in the conventional composite resin + fiber
Shah et alii., 2020	Polyethylene fiber Ribbond® (Ribbond Inc.)	Buccal; lingual and pulpal walls	Positive control (PC) Healthy teeth Negative control (NC) Unrestored cavity preparation	***Experimental Groups** - G_4**: 797.9 (17.7); **G_5**: 834.7 (26.3); **G_6**: 843.9 (39.8) ***Control Groups** - PC:** 1207.4 (90.6); **NC**: 669.6 (15.0); **non-fiber-reinforcement composite: G_1**: 879.9 (36.3); **G_2:** 873.6 (38.3); **G_3**: 922.6 (23.3); **G_7:** 697.7 (34.9); **G_8:** 705.4 (18.5); **G_9:** 713.0 (11.6)	Fibre reinforced composites when used in different cavity configurations of endodontically treated premolar yielded similar results

Table 2 - continues

Bahari et alii., 2019	Fiberglass Interlig® (Angelus) Fiberglass post Reforpost® (Angelus) Fiberglass post + Fiberglass	Buccal and lingual walls Horizontal transfixation on buccal and palatal walls Horizontal on buccal and palatal walls + occlusal position	Positive control (PC) Healthy teeth Negative control (NC) Unrestored cavity preparation	***Experimental Groups**** **-** **G_4**: 1122.1 (231.6); **G_5**: 1023.3 (295.5); **G_6**: 1097.5 (256.0) ***Control Groups**** **- PC:** 1073.6 (245.1); **NC**: 461.8 (136.2); **non-fiber-reinforcement composite: G_3**: 1103.5 (378.4)	Fiber reinforcement has no additional reinforcing effect on fracture strength of composite resin-restored endodontically treated maxillary premolars
Dalkiliç et alii., 2019	Polyethylene fiber Ribbond® (Ribbond Inc.)	Buccal; lingual and pulpal walls. Fiber in base of cavity + occlusal position	Healthy teeth (HT)	***Experimental Groups**** **-** **G_4**: 818.9 (166.1); **G_5**: 821.9 (226.3); **G_7**: 803.3 (78.1); **G_8**: 832.0 (209.2) ***Control Groups**** **- HT_1**: 1351.4 (238.8); **HT_2** : 1210.0 (318.5); **non-fiber-reinforcement composite: G_3**: 736.8 (116.4); **G_6**: 788.7 (210.5)	Fiber insertion with different techniques did not increase the fracture strength of teeth restored with bulk-fill composites
Jalan et alii., 2019	Polyethylene fiber Ribbond® (Ribbond Inc.)	Buccal; lingual and pulpal walls. Fiber on the occlusal surface.	Healthy teeth (HT)	***Experimental Groups**** **-** **G_3:** 1114.5 (429.9); **G_4:** 725.9 (118.7) ***Control Groups**** **- HT**: 914.3 (695.2); **non-fiber reinforcement composite: G_2**: 984.6 (403.4)	Fibre reinforcement in base of cavity can prove an alternate technique as a permanent restoration after root canal treatment
Mergulhão et alii., 2019	Fiberglass post White Post DC™ (FGM)	Horizontal on the buccal and palatal walls	Healthy teeth (HT)	***Experimental Group**** **-** **G_3**: 934.5 (233.6) ***Control Groups**** **- HT**: 949.6 (331.5); **non-fiber reinforcement composite: G_2**: 999.6 (352.50); **G_4**: 771.0 (147.4)	Endodontically treated maxillary premolars restored with conventional composite resin with or without horizontal fiber post; bulk-fill composite; and ceramic inlay showed fracture resistance like that of sound teeth
Sáry et alii., 2019	Polyethylene fiber Ribbond® (Ribbond Inc.) Fiberglass: EverStick NET® (GC Corporation)	Buccal/lingual in base of cavity; on the top; as an occlusal splint; circumferentially or transcoronaly. Buccal/lingual in base of cavity; on the top; as an occlusal splint or circumferentially	Healthy teeth (HT)	***Experimental Groups**** **-** **G_3**: 1122.2 (440.0); **G_4**: 1408.6 (314.5); **G_5**: 1925.6 (792.6); **G_6**: 2067.3 (535.8); **G_7**: 1834.4 (578.5); **G_8**: 2022.0 (771.4); **G_9**: 2129.2 (629.7); **G_{10}**: 1906.9 (538.0); **G_{11}**: 2484.8 (682.9) ***Control Groups**** **- HT**: 2266.3 (601.1); **non-fiber reinforcement composite: G_1**: 1629.4 (503.1); **G_2**: 1746.2 (467.5)	Incorporating polyethylene or a combination of short and bidirectional glass fibers in certain positions in direct restorations seems to be able to restore the fracture resistance of sound molar teeth
Göktürk et alii., 2018	Fiberglass Interlig® (Angelus)	Buccal and lingual walls	Positive control (PC) Healthy teeth Negative control (NC) Unrestored cavity preparation	***Experimental Group**** **-** **G_4**: 367.1 (82.9) ***Control Groups**** **- PC**: 742.0 (245.4); **NC**: 192.1 (59.3); **non-fiber reinforcement composite**: **G_3**: 355.8 (103.9)	All the restoration techniques increased the fracture resistance of teeth. There were no significant differences between the fracture resistance values of the groups that underwent different restorations

Table 2 - continues

Hshad et alii., 2018	Polyethylene fiber Ribbond® (Ribbond Inc.)	Buccal; lingual and pulpal walls	Healthy teeth (HT)	***Experimental Group** - G_3**: 1951.6 (330.9) ***Control Groups** - HT**: 2156.7 (628.0); **non-fiber reinforcement composite: G_2**: 1315.8 (352.3); **G_4**: 1445.3 (506.1)	Polyethylene fiber considerably increases the fracture resistance of mandibular premolar teeth with MOD cavities restored with composite
Khan et alii., 2018	Polyethylene fiber Ribbond® (Ribbond Inc.) Fiberglass EverStick® (GC Corporation); Dentapreg® (Advanced Dental Materials); Bioctris® (Bio Composants Medicaux)	Buccal; lingual and pulpal walls	Positive control (PC) Healthy teeth Negative control (NC) Unrestored cavity preparation	***Experimental Groups** - G_4**: 959.28 (128.67); **G_5**: 1433.14 (98.57); **G_6:** 979.17 (124.22); **G_7**: 1480.20 (102.90) ***Control Groups** - PC**: 1677.08 (155.19); **NC**: 352.54 (32.74); **non-fiber-reinforcement composite**: **G_3**: 775.14 (101.93)	All the groups restored with fiber displayed higher fracture resistance than the group restored with only composite resin. E glass fibers demonstrated highest fracture resistance and hence can be preferred over other fiber types.
Eapen et alii., 2017	Fiberglass Interlig® (Angelus)	Buccal; lingual and pulpal walls	Positive control (PC) Unrestored cavity preparation Negative control (NC) Healthy teeth	***Experimental Group** - G_5**: 404.31 (94.25) ***Control Groups** - PC**: 233.88 (26.42); **NC**: 842.52 (294.41); **non-fiber-reinforcement composite**: **G_3**: 434.56 (174.31); **G_4**: 465.13 (159.36); **G_6**: 712.80 (79.84)	Short fiber-reinforced composite can be used as a direct core buildup material that can effectively resist heavy occlusal forces against fracture and may reinforce the remaining tooth structure in endodontically treated teeth
Garlapati, Krithikadatta and Natanasabapathy, 2017	Polyethylene fiber Ribbond® (Ribbond Inc.)	Buccal; lingual and pulpal walls	Positive control (PC) Healthy teeth Negative control (NC) Unrestored cavity preparation	***Experimental Group** - G_4**: 1716.70 (199.50) ***Control Groups** - PC**: 1568.40 (221.70); **NC**: 891.00 (50.10); **non-fiber reinforcement composite**: **G_3**: 1418.30 (168.70); **G_5**: 1994.80 (254.20)	Endodontically treated teeth restored with EverX posterior fiber reinforced composite showed superior fracture resistance
Tekçe et alii., 2017	Polyethylene fiber Ribbond® (Ribbond Inc.)	Buccal; lingual and pulpal walls	Positive control (PC) Healthy teeth Negative control (NC) Unrestored cavity preparation	***Experimental Groups** - G_1**: 2254.10 (324.80); **G_2** 2228.60 (409.30); **G_3:** 2007.40 (495.60); **G_4:** 1938.20 (199.70) ***Control Groups** - PC**: 2910.30 (361.00); **NC:** 719.30 (108.60); **non-fiber-reinforcement composite**: **G_5**: 2142.90 (411.50)	Ribbon or short fiber-reinforced composites modestly increased the fracture strength of unfilled teeth. Polyethylene fiber-reinforced composite groups displayed similar fracture resistance results with those of the EverX Posterior group
Ozsevik et alii., 2016	Polyethylene fiber Ribbond® (Ribbond Inc.)	Buccal; lingual and pulpal walls	Positive control (PC) Healthy teeth Negative control (NC) Unrestored cavity preparation	***Experimental Group** - G_4:** 1958.00 (362.94) ***Control Groups** - PC**: 2859.50 (551.27); **NC:** 318.97 (108.67); **non-fiber-reinforcement composite**: **G_3**: 1489.50 (505.04); **G_5**: 2550.70 (586.10)	Fiber-reinforced composite under composite restorations resulted in fracture resistance similar to that of intact teeth. Furthermore, it reinforced root-filled teeth more than composite alone and ribbon and composite restorations

Table 2 - continues

Rahman et alii., 2016	Polyethylene fiber Ribbond® (Ribbond Inc.)	Buccal/lingual on the occlusal surface; buccal/lingual in base of cavity; buccal/lingual in base of cavity + fiber on the occlusal surface	Non-fiber-reinforcement composite restorations	***Experimental Groups*** *** - G_2:** 1236.82 (83.49); **G_2:** 879.31 (98.22); **G_2:** 1482.09 (74.57) ***Control Group*** *** - G_1**: 653.40 (74.01)	Polyethylene fiber inserted over or under the restoration significantly increased the fracture resistance of the root canal-treated teeth and maximum fracture resistance was observed when cavity was restored using dual-fiber technique
Kemaloglu et alii., 2015	Polyethylene fiber Ribbond® (Ribbond Inc.)	Buccal; lingual and pulpal walls.	Non-fiber-reinforcement composite restorations	***Experimental Group*** *** - G_2:** 919.86 (47.67) ***Control Groups*** *** - G_1**: 823.35 (34.05); **G_3**: 889.43 (72.87); **G_4**: 817.10 (60.82)	Fiber-reinforcement improved the fracture RESISTANCE of teeth with large MOD cavities treated endodontically
Karzoun et alii., 2015	Fiberglass post White Post DC™ (FGM)	Fiber post through the buccal and lingual walls	Positive control (PC) Healthy teeth Negative control (NC) Unrestored cavity preparation	***Experimental Groups*** *** - G_4:** 961.30 (245.20); **G_5:** 656.05 (139.40) ***Control Groups*** *** - PC**: 994.50 (147.30); **NC:** 411.80 (104.00); **non-fiber-reinforcement composite**: **G_3**: 482.1 (72.90)	Using a horizontal fiberglass post to restore endodontically treated MOD cavities increased the fracture resistance of the restoration-tooth unit significantly
Khan et alii., 2013	Polyethylene fiber Ribbond® (Ribbond Inc.) Fiberglass Vectris® (Ivoclar)	Buccal; lingual and pulpal walls.	Positive control (PC) Healthy teeth Negative control (NC) Unrestored cavity preparation	***Experimental Groups*** *** - G_5:** 958.60 (54.32); **G_6:** 913.20 (43.27) ***Control Groups*** *** - PC**: 1598.80 (89.67); **NC:** 393.70 (23.82); **non-fiber-reinforcement composite**: **G_3**: 729.30 (61.89); **G_4**: 699.70 (56.12)	Polyethylene and fiberglass under MOD composite restorations significantly increased fracture strength with no statistical difference between the two groups
Singh et alii., 2013	Polyethylene fiber Ribbond® (Ribbond Inc.)	Fiber strip in bucco-lingually oriented groove on the restorations occlusal surface. Fiber on the buccal; lingual and pulpal walls.	Positive control (PC) Healthy teeth Negative control (NC) Unrestored cavity preparation	***Experimental Groups*** *** - G_3:** 1236.82 (83.49); **G_4:** 879.31 (98.22) ***Control Groups*** *** - PC**: 1674.01 (99.78); **NC:** 379.65 (34.93); **non-fiber-reinforcement composite**: **G_2**: 653.4 (74.01)	Polyethylene fiber inserted over or under the restoration significantly increased the fracture strength of the root canal treated teeth and when the fiber was placed on the occlusal surface of the restoration from a buccal to lingual direction significantly higher fracture resistance was observed

[(1)]SD-standard deviation
*The designation of groups appears represented as in vitro studies
G: Group; MOD; Mésio-occlusal-distal

Twenty-two studies tested molars and/or premolars with mésio-occlusal-distal cavities (MOD), while one study used extracted molars with mésio-occlusal cavities (MO) (Bainy et alii., 2021) and another worked-in all occlusal cavities, MOD and MO cavities (Shah et alii., 2020). Twenty studies used teeth with root canal treatment and four studies did not perform any root canal treatment on the extracted teeth (Sáry et alii., 2019; Agrawal, Shah and Kapoor, 2022; Albar and Khayat, 2022; Özüdoğru and Tosun, 2022). Two studies used and evaluated the glass fibers effects (Eapen et alii., 2017; Göktürk et alii., 2018), two studies used fiberglass posts-devices (Karzoun et alii., 2015; Mergulhão et alii., 2019), two studies fiberglass fibers and post devices (Bahari et alii., 2019; Bainy et alii., 2021), three studies compared glass and polyethylene fibers (Khan et alii., 2013; Khan et alii., 2018; Sáry et alii., 2019) and the other fifteen tested only polyethylene fibers.

The outcomes of the in vitro studies performed by Khan et alii., 2013; Singh et alii., 2013; Karzoun et alii., 2015; Rahman et alii., 2016; Hshad et alii., 2018; Khan et alii., 2018; Sáry et alii., 2019; Bainy et alii., 2021; Shafiei et alii., 2021; Agrawal, Shah and Kapoor, 2022; Albar and Khayat, 2022; Balkaya et alii., 2022, reported increased fracture resistance mean values in the groups of fiber-reinforced composite restorations compared to groups of non-fibers-reinforced composite restorations. In three in vitro trials, results indicated that fiber-reinforced composite restorations group had lower fracture resistance mean values than to non-fibers-reinforced composite restorations (Ozsevik et alii., 2016; Eapen et alii., 2017; Garlapati, Krithikadatta and Natanasabapathy, 2017) and, in nine studies, authors reported no significant difference for the fracture resistance mean values of the several groups tested. Comparing healthy teeth and teeth with fiber-reinforced composites restorations results, twelve studies registered higher values of fracture resistance for the control, healthy teeth but another's six studies (Karzoun et alii., 2015; Ozsevik et alii., 2016; Hshad et alii., 2018; Bahari et alii., 2019; Jalan et alii., 2019; Mergulhão et alii., 2019) outputs do not support those findings, with significant difference registered between them. However, Garlapati, Krithikadatta and Natanasabapathy, 2017 as well as Sáry et alii., 2019 reported fracture resistance mean values significantly higher for the group with fiber-reinforced composites restorations than those obtained for extracted healthy teeth. In all in vitro protocols that defined as control group unrestored cavity preparations, of the mean values for fracture resistance obtained were always lower than the interventional fiber-reinforced composite restorations, and the other control group, the healthy teeth.

Qualitative analysis of the 24 in vitro studies, according to variability of the materials used in the experimental group and each control groups are showed in **Table 3**. The variability of methods and design performed in all studies is described in **Table 4**.

2. Quality assessment of the included in vitro trials

The detailed assessment of the methodological quality of the studies is shown in **Table 5**. Twenty-three studies had medium risk of bias. A single study had a high risk of bias (Singh et alii., 2013). All 24 in vitro studies analyzed presented clearly stated aims/objectives which should then be followed throughout (criteria 1) as well as details of comparison group (positive control, negative control, or standard) (criteria 4). Most studies were adequately specific about the details regarding predefined population from which sample has been selected (criteria 3), detailed explanation of methodology (criteria 5), method of measurement of outcome (criteria 8), details regarding statistical analysis (criteria 11) and outcome should be based on predefined aims and/or objectives (criteria 12). The majority of trials did not present detailed explanation of sample size calculation (criteria 2) on either information about the number of operators and details regarding training and calibration of operator/s (criteria 6). None of the studies explained or presented the method of randomization (criteria 7), number of outcome assessors and details regarding training and calibration of assessor/s (criteria 9) or blinding of operator(s), outcome assessor(s), and statistician (criteria 10).

Table 3 - Qualitative systematic analysis of the 24 in vitro studies reviewed, according to variability of the materials used in the experimental (Exp) and the control (C_1, C_2, C_3) groups, number of references and reference.

	Material variables of the in vitro studies	Number of references (*n*)	In vitro references
Variability: Type of fiber (composition)	**Polyethylene fiber:** Ribbond® (Ribbond Inc.) ultra-high molecular weight polyethylene fibers	15	Agrawal, Shah and Kapoor, 2022; Albar and Khayat, 2022; Balkaya et alii., 2022; Özüdoğru and Tosun, 2022; Shafiei et alii., 2021; Shah et alii., 2020; Dalkiliç et alii., 2019; Jalan et alii., 2019; Hshad et alii., 2018; Garlapati, Krithikadatta and Natanasabapathy, 2017; Tekçe et alii., 2017; Ozsevik et alii., 2016; Rahman et alii., 2016; Kemaloglu et alii., 2015; Singh et alii., 2013
	Fiberglass: Interlig® (Angelus) Braided fiberglass pre-impregnated with BIS-GMA	2	Göktürk et alii., 2018; Eapen et alii., 2017
	Fiberglass: Interlig®(Angelus) Braided fiberglass pre-impregnated with BIS-GMA + **Fiberglass post:** Reforpost® (Angelus) Fiberglass, pigmented resin, stainless steel filament	2	Bainy et alii., 2021; Bahari et alii., 2019
	Fiberglass post: White Post DC™ (FGM) fiberglass, epoxy resin	2	Mergulhão et alii., 2019; Karzoun et alii., 2015
	Fiberglass and Polyethylene fiber EverStick® (GC Corporation) bidirectional silanized fiberglass pre-impregnated with BIS-GMA and PMMA + Ribbond® (Ribbond Inc.)	1	Sáry et alii., 2019
	EverStick® (GC Corporation) bidirectional silanized fiberglass pre-impregnated with BIS-GMA and PMMA; Dentapreg® (ADM) Braided silanized fiberglass pre-impregnated with dimethacrylate; Bioctris® (Bio Composants Medicaux) Unidirectional fiberglass impregnated with dimethacrylate + Ribbond® (Ribbond Inc.)	1	Khan et alii., 2018
	Vectris® (Ivoclar, Vivadent) Braided silanized fiberglass pre-impregnated with BIS-GMA/TEGDMA + Ribbond® (Ribbond Inc.)	1	Khan et alii., 2013
Variability: Resin-based composite (Fillers composition)	**Short fiber reinforced composite** Ever-X Posterior™ (GC Corporation) E-glass Fiber, Barium Glass, BIS-GMA, PMMA, BIS-MEPP, TEGDMA, UDMA/High viscosity	9	Agrawal, Shah and Kapoor, 2022; Balkaya et alii., 2022; Shah et alii., 2020; Sáry et alii., 2019; Eapen et alii., 2017; Garlapati, Krithikadatta and Natanasabapathy, 2017; Tekçe et alii., 2017; Ozsevik et alii., 2016; Kemaloglu et alii., 2015
	Composite Microhybrid		
	G-ænial posterior™ (GC Corporation) Composite Microhybrid/High viscosity	5	Agrawal, Shah and Kapoor, 2022; Özüdoğru and Tosun, 2022; Sáry et alii., 2019; Tekçe et alii., 2017; Ozsevik et alii., 2016
	Filtek Z250™ (3M ESPE) Composite Micro hybrid/High viscosity	3	Albar and Khayat, 2022; Göktürk et alii., 2018; Rahman et alii.,2016
	Te-Econom Plus® (Ivoclar Vivadent) Composite Microhybrid/High viscosity	3	Shah et alii., 2020; Khan et alii., 2018; Garlapati, Krithikadatta and Natanasabapathy, 2017
	Clearfil AP-X™ (Kuraray) Composite Microhybrid/High viscosity	1	Hshad et alii., 2018
	Filtek P60™ (3M ESPE) Composite Microhybrid/High viscosity	1	Eapen et alii., 2017
	Composite Nanohybrid		
	Filtek Z350XT™ (3M ESPE) Composite Nanohybrid/High viscosity	1	Mergulhão et alii., 2019
	Filtek Z550™ (3M ESPE) Composite Nanohybrid/High viscosity	2	Balkaya et alii., 2022; Kemaloglu et alii., 2015
	Tetric N-Ceram® (Ivoclar, Vivadent) Composite Nanohybrid/High viscosity	2	Shafiei et alii., 2021; Eapen et alii., 2017

Table 3 - continues

	Venus® (Heraeus Kulzer) Composite Nanohybrid/High viscosity	1	Khan et alii., 2013
	Filtek Z250XT™ (3M ESPE) Composite Nanohybrid/High viscosity	2	Jalan et alii., 2019; Karzoun et alii., 2015
	Composite Hybrid: Valux Plus™ (3M ESPE) Composite Hybrid/High viscosity	1	Bahari et alii., 2019
Variability: Resin-based composite clinical consistency (bulk fill, flow, regular)	**Bulk-Fill Composite**		
	Filtek Bulk Fill™ (3M ESPE) Bulk-Fill Composite/High viscosity	2	Balkaya et alii., 2022; Mergulhão et alii., 2019
	Tetric N-Ceram® (Ivoclar, Vivadent) Bulk-Fill Composite/High viscosity	1	Shafiei et alii., 2021
	Single-Fill™ (Kerr Corporation) Bulk-Fill Composite/High viscosity	1	Bainy et alii., 2021
	Composite Bulk-Fill Flow		
	Filtek Bulk Fill Flow™ (3M ESPE) Bulk-Fill /Low viscosity	3	Bainy et alii., 2021; Mergulhão et alii., 2019; Kemaloglu et alii., 2015
	Estelite Bulk-Fill Flow® (Tokuyama) Bulk-Fill/Low viscosity	1	Dalkiliç et alii., 2019
	X-tra base® (Voco) Bulk-Fill/Low viscosity	1	Shafiei et alii., 2021
	SDR Flow® (Dentsply) Bulk-Fill/Low viscosity	2	Balkaya et alii., 2022; Tekçe et alii., 2017
	Venus Flow® (Heraeus Kulzer) Bulk-Fill/Low viscosity	1	Khan et alii;, 2013
	Composite Flow		
	G-ænial Flo™ (GC Corporation) Composite/Low viscosity	2	Sáry et alii., 2019; Tekçe et alii., 2017
	Filtek Flow™ (3M ESPE) Composite/Low viscosity	4	Bahari et alii., 2019; Göktürk et alii., 2018 ; Garlapati, Krithikadatta and Natanasabapathy, 2017; Rahman et alii.,2016
	Tetric N-Flow® (Ivoclar, Vivadent) Composite/Low viscosity	3	Shafiei et alii., 2021; Jalan et alii., 2019; Eapen et alii., 2017
	Te-econom Flow® (Ivoclar, Vivadent) Composite/Low viscosity	1	Khan et alii., 2018
	Estelite Flow Quick® (Tokuyama) Composite/Low viscosity	1	Dalkiliç et alii., 2019
	Opallis Flow™ (FGM Dental Group) Composite/Low viscosity	1	Albar and Khayat, 2022
	Clearfil Majesty Flow™ (Kuraray) Composite/Low viscosity	1	Hshad et alii., 2018
	Competence Flow® (WP) Composite/Low viscosity	1	Ozsevik et alii., 2016
Variability: Other Resin-based composites non-fiber-reinforced	RelyX Ultimate™ (3M ESPE) Dual Curing Adhesive Resin Cement	2	Mergulhão et alii., 2019; Karzoun et alii., 2015
	Bisco Duolink® (Bisco Inc.) Dual Curing Adhesive Resin Cement	1	Göktürk et alii., 2018
	MultiCore Flow® (Ivoclar,Vivadent) Self-curing composite core build-up materials with light curing option	1	Eapen et alii., 2017
	IPS e.max® (Ivoclar, Vivadent) Lithium disilicate glass ceramic	1	Mergulhão et alii., 2019
	Vita Enamic® (Vita) Hybrid ceramic	1	Göktürk et alii., 2018
Variability: Control groups (C_1, C_2, C_3)	**C_1**-Healthy teeth	6	Özüdoğru and Tosun, 2022; Dalkiliç et alii., 2019; Jalan et alii., 2019; Mergulhão et alii., 2019; Sáry et alii., 2019; Hshad et alii., 2018
	C_1-Healthy teeth and **C_3**-Unrestored cavity preparations	14	Balkaya et alii., 2022; Bainy et alii., 2021; Shafiei et alii., 2021; Shah et alii.,2020; Bahari et alii., 2019; Göktürk et alii., 2018; Khan et alii., 2018; Eapen et alii., 2017; Garlapati, Krithikadatta and Natanasabapathy, 2017; Tekçe et alii., 2017; Ozsevik et alii., 2016; Karzoun et alii., 2015; Khan et alii., 2013; Singh et alii., 2013
	C_2-Non-fiber-reinforced composite restorations	4	Agrawal, Shah and Kapoor, 2022; Albar and Khayat, 2022; Rahman et alii., 2016; Kemaloglu et alii., 2015

Table 4 - Qualitative systematic analysis of the 24 in vitro studies reviewed, according to variability of the methods/design performed, number of references, sample (*n*) and reference.

Methods/design variable of the in vitro studies		Number of references (*n*)	In vitro references
Variability: Teeth type	Premolars	15	Agrawal, Shah and Kapoor, 2022; Balkaya et alii., 2022; Shafiei et alii., 2021; Shah et alii., 2020; Bahari et alii., 2019; Dalkiliç et alii., 2019; Jalan et alii., 2019; Mergulhão et alii., 2019; Göktürk et alii., 2018; Hshad et alii., 2018; Eapen et alii., 2017; Rahman et alii.,2016; Kemaloglu et alii., 2015; Karzoun et alii., 2015; Singh et alii., 2013
	Molars	8	Özüdoğru and Tosun, 2022; Bainy et alii., 2021; Sáry et alii., 2019; Khan et alii., 2018; Garlapati, Krithikadatta and Natanasabapathy, 2017; Tekçe et alii., 2017; Ozsevik et alii., 2016; Khan et alii., 2013
	Premolars and molars	1	Albar and Khayat, 2022
Variability: Strain rate millimeter/minute (mm/min) of the compressive force applied	0.5 mm/min	11	Agrawal, Shah and Kapoor, 2022; Albar and Khayat, 2022; Bainy et alii., 2021; Shah et alii., 2020; Bahari et alii., 2019; Hshad et alii., 2018; Khan et alii., 2018; Garlapati, Krithikadatta and Natanasabapathy, 2017; Rahman et alii.,2016; Khan et alii., 2013; Singh et alii., 2013
	1 mm/min	12	Balkaya et alii., 2022; Özüdoğru and Tosun, 2022; Shafiei et alii., 2021; Dalkiliç et alii., 2019; Jalan et alii., 2019; Mergulhão et alii., 2019; Göktürk et alii., 2018; Eapen et alii., 2017; Tekçe et alii., 2017; Ozsevik et alii., 2016; Kemaloglu et alii., 2015; Karzoun et alii., 2015
	2 mm/min	1	Sáry et alii., 2019
Variability: Load cell diameter in millimeter(mm)	2 mm	2	Agrawal, Shah and Kapoor, 2022; Jalan et alii., 2019
	3 mm	2	Albar and Khayat, 2022; Dalkiliç et alii., 2019
	4 mm	1	Göktürk et alii., 2018
	5 mm	4	Özüdoğru and Tosun, 2022; Ozsevik et alii., 2016; Rahman et alii.,2016; Singh et alii., 2013
	6 mm	11	Balkaya et alii., 2022; Shafiei et alii., 2021; Shah et alii., 2020; Mergulhão et alii., 2019; Sáry et alii., 2019; Hshad et alii., 2018; Khan et alii., 2018; Eapen et alii., 2017; Garlapati, Krithikadatta and Natanasabapathy, 2017; Karzoun et alii., 2015; Khan et alii., 2013
	6.25 mm	1	Bahari et alii., 2019
	6.5 mm	1	Bainy et alii., 2021
	8 mm	1	Tekçe et alii., 2017
	Not applicable	1	Kemaloglu et alii., 2015
Variability: Thermocycling temperature (°C) **Minimum-Maximum (Min-Max)**	Min-Max: 5°C - 55°C	14	Agrawal, Shah and Kapoor, 2022; Albar and Khayat, 2022; Balkaya et alii., 2022; Özüdoğru and Tosun, 2022; Bainy et alii., 2021; Shafiei et alii., 2021; Dalkiliç et alii., 2019; Mergulhão et alii., 2019; Göktürk et alii., 2018; Khan et alii., 2018; Tekçe et alii., 2017; Ozsevik et alii., 2016; Rahman et alii.,2016; Kemaloglu et alii., 2015
	Min-Max: 15°C - 45°C	2	Shah et alii., 2020; Garlapati, Krithikadatta and Natanasabapathy, 2017
	Not applicable	8	Bahari et alii., 2019; Jalan et alii., 2019; Sáry et alii., 2019; Hshad et alii., 2018; Eapen et alii., 2017; Karzoun et alii., 2015; Khan et alii., 2013; Singh et alii., 2013
Variability: Number thermocycling cycles	500	3	Agrawal, Shah and Kapoor, 2022; Bainy et alii., 2021; Rahman et alii.,2016
	600	1	Özüdoğru and Tosun, 2022
	1000	1	Tekçe et alii., 2017
	5000	5	Balkaya et alii., 2022; Shafiei et alii., 2021; Shah et alii., 2020; Mergulhão et alii., 2019; Ozsevik et alii., 2016
	6000	1	Khan et alii., 2018
	10000	4	Albar and Khayat, 2022; Dalkiliç et alii., 2019; Göktürk et alii., 2018; Kemaloglu et alii., 2015
	Not applicable	9	Bahari et alii., 2019; Jalan et alii., 2019; Sáry et alii., 2019; Hshad et alii., 2018; Eapen et alii., 2017; Garlapati, Krithikadatta and Natanasabapathy, 2017; Karzoun et alii., 2015; Khan et alii., 2013; Singh et alii., 2013

Table 5 - Quality results of the in vitro studies according to the QUIN assessment tool (Sheth et alii., 2022).

Identification number of in vitro Studies selected (Reference)	1. Clearly stated aims/objectives	2. Sample size calculation	3. Explanation of sampling technique	4. Comparison group	5. Methodology	6.Operator details	7.Randomization	8. Method of measurement of outcome	9. Outcome assessor details	10. Blinding	11. Statistical analysis	12.Presentation of results	Risk of Bias*
Agrawal, Shah and Kapoor, 2022	2	0	2	2	2	0	0	2	0	0	2	2	**Medium**
Albar and Khayat, 2022	2	2	2	2	2	0	0	2	0	0	2	2	**Medium**
Balkaya et alii., 2022	2	2	2	2	2	0	0	2	0	0	2	2	**Medium**
Özüdoğru and Tosun, 2022	2	0	2	2	2	1	0	2	0	0	2	2	**Medium**
Bainy et alii., 2021	2	2	2	2	2	0	0	2	0	0	2	2	**Medium**
Shafiei et alii., 2021	2	0	2	2	2	0	0	2	0	0	2	2	**Medium**
Shah et alii., 2020	2	0	2	2	2	0	0	2	0	0	2	2	**Medium**
Bahari et alii., 2019	2	2	2	2	2	0	0	2	0	0	2	2	**Medium**
Dalkiliç et alii., 2019	2	0	2	2	2	0	0	2	0	0	2	2	**Medium**
Jalan et alii., 2019	2	0	2	2	2	0	0	2	0	0	1	1	**Medium**
Mergulhão et alii., 2019	2	0	2	2	2	0	0	2	0	0	2	2	**Medium**
Sáry et alii., 2019	2	0	2	2	2	1	0	2	0	0	2	2	**Medium**
Göktürk et alii., 2018	2	0	2	2	2	1	0	2	0	0	2	2	**Medium**
Hshad et alii., 2018	2	0	2	2	2	0	0	2	0	0	2	2	**Medium**
Khan et alii., 2018	2	0	2	2	2	0	0	2	0	0	2	2	**Medium**
Eapen et alii., 2017	2	0	2	2	2	0	0	2	0	0	2	2	**Medium**
Garlapati, Krithikadatta and Natanasabapathy, 2017	2	0	2	2	2	0	0	2	0	0	1	2	**Medium**
Tekçe et alii., 2017	2	0	2	2	2	0	0	2	0	0	2	2	**Medium**
Ozsevik et alii., 2016	2	2	2	2	2	0	0	2	0	0	2	2	**Medium**
Rahman et alii.,2016	2	0	2	2	2	0	0	2	0	0	1	2	**Medium**
Kemaloglu et alii., 2015	2	0	2	2	2	0	0	2	0	0	1	2	**Medium**
Karzoun et alii., 2015	2	0	2	2	2	1	0	2	0	0	2	2	**Medium**
Khan et alii., 2013	2	0	2	2	2	0	0	2	0	0	1	2	**Medium**
Singh et alii., 2013	2	0	1	2	1	0	0	1	0	0	1	1	**High**

* Score: Adequately Specified=2; inadequately Specified=1; Not Specified (NS)= 0; Not Applicable (NA).
Final Score: Total score×100/ 2×number of criteria applicable. >70%=low risk of bias; 50%-70%=medium risk of bias and <50%=high risk of bias.

3. Study Quantitative results

The highest median value for fracture resistance was exhibited by the control group, healthy tooth (1459.9 [962.6 to 2238.92] N), followed by the experimental group teeth with fiber-reinforced composites restoration (976.0 [832.0 to 1834.4] N) and then, by both control groups, the non-fiber composite restoration (771.0 [592.2 to 1209.6] N) and the unrestored cavity preparation (386.6 [297.6 to 682.0] N). The mean, median, minimum, maximum and interquartile values for each group are showed in **Table 6**.

Table 6 - Fracture resistance values distribution and dispersion of the fracture resistance values calculated for the experimental fiber-reinforced-composite restoration (Exp) and the control groups, C_1 (healthy teeth), C_2 (non-fiber-reinforced composite restoration) and C_3 (unrestored cavity preparation). Systematic results of the 24 in vitro outputs.

Experimental and Control Groups	Posterior Teeth (Sample) n [(1)]	Fracture Resistance values (Newton, N)					
		Mean	Median	Minimum	Maximum	Interquartile Range (Q_1-Q_3)	*p*-Value [(2)]
Exp - Fiber-reinforced composite restoration	55	1230.1	976.0	367.1	2602.1	832.0 to 1834.4	0.474
C_1 - Healthy teeth	20	1660.8	1459.9	742.1	3563.0	962.6 to 2238.9	0.457
C_2 - Non-fiber-reinforced composite restoration	45	956.3	771.0	355.8	2550.7	592.2 to 1209.6	0.471
C_3 - Unrestored cavity preparation	14	471.1	386.6	192.1	1001.0	297.6 to 682.0	0.450

[(1)] *n*: number of human posterior teeth/specimens in each group. [(2)] Intra-group analysis. Kruskal-Wallis test ($p<0.05$).

The results of Kolmogorov-Smirnov test showed non-normal distribution ($p<0.05$) for all the mean values of fracture resistance of the experimental and control groups as is presented in **Figure 3** (Annex II). Comparison between all experimental and control groups showed differences (Kruskal-Wallis test, $p<0.001$) for median values of fracture resistance as presented in **Table 7** and **Figure 4** (Annex III).

Table 7 - Fracture resistance median and IQR values obtained for the experimental group (Exp) and for each control groups (C_1, C_2, C_3).

Experimental (Exp) and Control (C) Groups	Overall Fracture Resistance (Newton)			*p*-value[(3)]
	n[(1)]	Median value	IQR[(2)] values	
Exp - Fiber-reinforced composite restoration	55	976.0	832.0 to 1834.4	$p<0.001$
C_1 - Healthy teeth	20	1459.9	962.6 to 2238.9	
C_2 - Non-fiber-reinforced composite restoration	45	771.0	592.2 to 1209.6	
C_3 - Unrestored cavity preparation	14	386.6	297.6 to 682.0	

[(1)] n: number human posterior teeth/specimens per group. [(2)] IQR : interquartile range (Q_1-Q_3). [(3)] Kruskal-Wallis test ($p<0.05$).

Pairwise comparison among the fiber-reinforced composite restoration group and each C_1, C_2, C_3 control groups (**Table 8**), reveled significant differences (Kruskal-Wallis test) for median values of tooth fracture resistance calculated for the experimental group and the healthy tooth (p=0.048), the non-fiber composite restoration (p=0.008) and the unrestored cavity preparation (p<0.001) tooth groups.

Table 8 - Pairwise comparison between experimental group (Exp) (fiber-reinforced composite restoration) and the control groups, C_1 (healthy teeth), C_2 (non-fiber-reinforced composite restoration) and C_3 (unrestored cavity preparation).

Pairwise comparisons of experimental and each control groups		
Sample 1 (1) **Experimental Group**	**Sample 2(1)** **Control groups**	***p* -value (2)**
Fiber-reinforced composite restoration	**C_1** - Healthy teeth	0.048
	C_2 - Non-fiber-reinforced composite restoration	0.008
	C_3 - Unrestored cavity preparation	<0.001

(1) Each line tests the null hypothesis that the distributions Sample 1 and Sample 2 are equal. The significance level is 0.05.
(2) Kruskal-Wallis test. Significance values were adjusted by the Bonferroni correction.

IV - DISCUSSION

The minimal loss of tooth structure makes the tooth more fragile and susceptible to fracture (Gaeta et alii., 2021). Among several restorative materials and technical options to reinforce the crown of a remaining tooth, the use of fibers associated with resin composites appears as a valid approach in attempting to reduce stress concentrations in load posterior oral locations and to strengthen residual dental tissues (Sadr et alii. 2020).

This study was registered (425509) in PROSPERO database, followed the PRISMA guidelines and independently assessed the quality of included studies using the QUIN tool. From 932 relevant articles, only 24 publications met the inclusion criteria, of which, 23 had moderate and one high risk of bias.

Were evaluated and compare the outcomes of 24 in vitro trials, performed in the last 10 years, that tested and quantified, in Newton, the fracture resistance of glass fibers and/or polyethylene fibers in extensive posterior composite direct restorations. This mechanical behavior, the fracture resistance mean values were collected and analyzed as, independent variables, distribution and dispersion. The median values of fracture resistance were then calculated, for the experimental group, fiber-reinforced composite restorations and, for all three control groups used in the 24 studies protocols namely, healthy teeth, non-reinforced composite restorations and unrestored cavity preparations, in order to detect the higher and lower values.

Pairwise comparison were performed, within and among, the experimental and the controls groups to detect if fracture resistance values for fiber reinforced composite restorations differs, or not, from those values calculated for the healthy teeth, for the non-fiber reinforced composite restorations or for the unrestored cavity preparations, of the posterior extracted human teeth specimens.

Based on the results of this systematic quantitative analysis, the null hypothesis was rejected, that is, the median value of fracture resistance of posterior teeth with fiber-reinforced composite restorations differs ($p<0.001$) from those of healthy teeth, or of non-fiber-reinforced composites restorations or of unrestored cavity preparations.

The highest median value of fracture resistance was of 1459.9 N, exhibited by the control group, the healthy tooth, followed by 976.0 N of the experimental group, the fiber-reinforced composites restorations. Both control groups, the non-fiber composite restoration and the unrestored cavity preparation, reveled lower values, of 771.0 N and 386.6 N, respectively, than the experimental group and the control, extracted healthy teeth.

Posterior teeth restored with fiber-reinforced composites were found to have improved high values of fracture resistance when compared to equivalent teeth restored with resin composites but with non-fiber-reinforcements. These improvements can be attributed a stress transfer from the polymer matrix of the resin composite within the fibers devices, which have high tensile strength, thus causing lower stress, to be transmitted to the remaining tooth structure. Thereby, fiber devices may be able to better promote a load spread and distribution within the resin composite restoration (Sáry et alii., 2019; Bainy et alii., 2021).

In the same analysis, the control group of healthy teeth, reported the higher values, so better, fracture resistance behavior, when compared to those of the fiber-reinforced composite restoration and the others control approach’s used in the 24 in vitro research protocols. Those findings emphasize the importance of the oral health preventive measures, for preserving the strengthening of health teeth but also, the minimally invasive conservative dentistry approach, in order to preserve dental hard tissues and tooth surfaces, as possible, during clinical procedures, as their amount and their structural integrity plays a major role in the natural resistance of the organ (Zhang et alii., 2014). The loss of tooth structure either by extensive cavity preparation, by restorative procedures and/or root canal treatments affects the biomechanical behavior and load stress distribution within the tooth, which is why restorative procedures and selected appropriate materials, besides replacing anatomical function and aesthetics, should also reinforce the remaining tooth structure (Neto et alii., 2021).

Our study also performed a qualitative systematic analysis of the 24 in vitro studies reviewed, according to variability of materials used as testing an as control, and also, the variability of test measurement a protocol designs. Materials variability in the in vitro studies were found for the fibers type, composition and position to be applied, for the direct resin composites filler composition and clinical consistency (bulk fill, flow and regular), for other types of resin composites used, for number of specimens included in the tested and the control groups. Variability of the in vitro protocols were also identified regarding the posterior (premolar and/or molar) teeth used, the strain rate of the compressive load applied (from 0.5mm/min up to 2mm/min), the load cell diameter of the testing device (range from 2 mm to 8mm), the specimens thermocycling temperature (5ºC to 55ºC) and number of cycles (500 to 10000).

Agrawal, Shah and Kapoor, 2022 as well as Balkaya et alii.,2022 in their in vitro outcomes, found better results for composite restorations reinforced with polyethylene fibers (Ribbond®, bondable reinforcement ribbon, Ribbond Inc., USA) when compared to restorations with EverX Posterior™ (GC, Europe) a fiber-reinforced composite designed by the manufacture to be used as dentin replacement, in conjunction with a namely, conventional composite. Hshad et alii., 2018 and Albar and Khayat, 2022, also reported increased fracture resistance values of teeth restored with polyethylene fibers compared to teeth restored without fibers. Shafiei et alii, 2021 found the same results when they combined Ribbond®, positioned at the background surface, both pulp and axial walls of the cavity preparation with a nanohybrid composite. Increased values for teeth fracture resistance were also achieved, by Rahman et alii., 2016, using dual polyethylene strips placed at the background wall and the occlusal surfaces of cavity preparations. Similarly outcome were found by Singh et alii., 2013 in their vitro study, where the best results corresponded to the tested group that applied both polyethylene fiber and resin composite, on the occlusal surface of the posterior restoration. All those results corroborate the findings of previous research, that using Ribbond® associated with resin composite, was achieved improvements for the mechanical behavior of tooth/restoration assembly (Belli et alii., 2005; Ayad, Maghrabi and García-Godoy, 2010).

Ribbond® device is described as a material composed of pre-impregnated, silanized, ultra-high molecular weight, plasma-treated polyethylene fibers, with leno woven design and a lock-stitch feature, allowing according, to some authors, forces spread throughout the weave without transferring back the stress loads within the composite (Belli et alii., 2006). According to some authors that registered best result incorporating polyethylene fibers to composite restorations, when those are adapted to the inner contours of the remaining tooth substrate, fracture protection mechanism are enhanced. The leno weave structure helps to spread the stress over a wider region by providing multiple loading paths so that polymerization shrinkage and occlusal loading stresses are distributed over an extensive surface. Incorporating those devices under a composite restoration is also suggested as a mean to reinforce the tooth by increasing the modulus of elasticity and preventing fractures (Deliperi, Alleman and Rudo, 2017).

In the study of Karzoun et alii., 2015, teeth restored with composite and horizontal fiberglass post devices provided higher fracture resistance than those restored with non-reinforced resin composite. These findings corroborate those achieved by Bainy et alii, 2021 in their study. These authors tested the use of fiber glass and fiberglass post and explained that using the transfixed, from buccal to lingual cavity surfaces, post on the tooth crown or placing a fiber covering all internal surfaces of the tooth cavity preparations, that procedures promotes reinforcement of the cusps, minimizing their deflection; effects that have also been described in some previous studies reported in the literature (Beltrão et alii., 2009; Oskoee et alii., 2009).

Sáry et alii, 2019 evaluated the fracture strength of restorations reinforced with Ribbond®, EverX Posterior™, and EverStick®NET (GC, Europe) using several restorative approaches. When Ribbond® was trans-coronally applied, higher values of fracture resistance were achieved, even slightly higher than those compared to the healthy tooth. The fibers occlusal positioning in a resin composite restoration, leaves them closer to the point of the loads application, keeps the buccal and lingual cusps together, and promote higher fracture resistance. Khan et alii, 2018, also tested the fracture resistance of four different types of fibers, finding that all groups restored with fibers showed higher fracture resistance than those with no fibers within the composite. Also, the groups with EverStick®NET and Bioctris® (Bio Composants Médicaux, France) showed higher fracture resistance values compared to

Ribbond® and Dentapreg® fiberfill (Dentapreg America Incorporated, USA). Those authors suggested that based on the fact that both, EverStick®NET and Bioctris® have unidirectional fibers and a semi-interpenetrating polymer network (semi-IPN) in their composition, that may improve the chemical bond with the conventional composite. They also stated that manual impregnation of the Ribbond® fibers may have been done improperly, leading to reduce adhesion between the polyethylene fibers and the resin composite matrix (Mangoush et alii., 2021).

Ozsevik et alii., 2016, and Garlapati, Krithikadatta and Natanasabapathy, 2017 in their studies compared teeth restored with composite and polyethylene fibers, the EverX Posterior™, with non-fiber filler composite restorations. The results revealed fracture resistance values statistically higher in restorations with EverX Posterior™ than those obtained for the healthy teeth, as control group. Similar results were resisted in Eapen et alii., 2017 study.

EverX Posterior™ is a resin composite with short E-glass fibers and barium glass particles (0.6 to 1.5 mm), randomly oriented within a cross-linked polymer matrix (semi-interpenetrating polymer network, semi IPN), with a total inorganic content of 76% by weight and of 57% by volume. Due to the size of fibers contents, that material is covered by a conventional resin layer, as it does not provide a desirable level for wear resistance or polishing (Garoushi et alii., 2013). According to some authors, the better results of EverX Posterior™ can be attributed to the incorporation of those short multidirectional and discontinuous fibers within the resin matrix. Those may play a significant role for improving mechanical properties, by relieving effects of polymerization shrinkage and marginal microleakage, and supporting the surface composite layer, preventing crack propagation in addition to the spread load (Lassila et alii., 2018).

However, Kemaloglu et alii., 2015; Tekçe et alii., 2017; and Shah et alii., 2020 studies did not find statistical differences between teeth restored with polyethylene fibers and teeth restored with short-fiber-reinforced composites, though fracture resistance values were higher values, in these two groups, than those of teeth restored with composite without fibers. One explanation for those results, may be related to the fact that placing the fiber reinforcement within the cavity preparations can be a technically sensitive procedure (Shah et alii., 2020). Resin composites impregnated with short glass fibers, clinically are easier to apply because it eliminates the need to apply the fibers separately within the cavities (Forster et alii., 2019). On the other hand, polyethylene fibers must be impregnated with wetting or bonding adhesive procedures, before its application, being a critical clinical step. Voids created within the matrix or excess of residual monomer can affect the interface of fibers and composite resin changing one or both materials properties and lead to restorations failure (Sadr et alii., 2020).

In the research conducted by Jalan et alii., 2019; and Özüdoğru and Tosun, 2022, results showed high fracture resistance values for polyethylene fiber-reinforced groups, but not statistically different to the control groups, the healthy teeth and the those restored with conventional composite. Those results may differ from other research due to different study settings such as root canal treatment, type of cavity, remaining wall thickness, and orientation of the fiber within the cavity. Dalkiliç et alii., 2019 study, also noted no significant differences for fracture resistance values in composite restorations with and without polyethylene fibers. An explanation for those results may be related to the structural properties of the tested composite material (Estelite Bulk-Fill flow®, Tokuyama), which contains a radical amplified photopolymerization initiator, coupled with camphoroquinone, promoting polymeric polymerization rates and mechanical properties.

As explained in the study of Mergulhão et alii., 2019 the discrepancies between studies outcomes can be adjudicated to the lack of standardized preparation techniques and testing designs of the several in vitro trials. In this study, more favorable results regarding restoration fractures were also determined in teeth restored with composites reinforced with fibers and post, compared to the teeth restored with composite without no fibers in it. The authors attribute those results to the relative coverage of the cusps with the composite resin during fiber placement and, to the relative ability of the fiber post to immobilize the buccal and lingual walls of cavity preparations.

Although the restoration techniques tested in the study of Göktürk et alii., 2018 increased the fracture resistance of the tested teeth, no significant differences were found between the fracture resistance values of teeth restored with composite, or with fiber-reinforced composite or with hybrid ceramic inlays. During this research, the pre-impregnated E-glass fibers were placed from buccal to lingual position within the cavity, explaining that the presence of those with the composite resin probably changed the modulus of elasticity of the material, modifying the distribution and transmission of stresses to the residual cavity walls as also reported by other authors (Nicola et alii., 2016).

A systematic review of in vitro studies was performed in the present work, even though they were initially designed for the purpose of analyzing clinical trials (Page et alii., 2021) as no clinical studies were found regarding our research question, our intention was to try to reach a consensus between the results of the several outcomes of laboratory studies, that are still contradictory.

The main limitation of our systematic review and statistical analysis of fracture resistance values of fiber-reinforced composite restorations, healthy teeth, non-fiber-reinforced composites restorations or unrestored cavity preparation consists on the high variability of the protocol of in vitro studies that included, sample size, tooth size and type, different restorative materials, manufacturers and technical procedures, the type, size orientation, adhesion to the polymer matrix and resin impregnation of the reinforcing fibers and the fracture resistance evaluation methods (different load values, size, load cell type and load application point); each one of those factors can directly influence the results (Krithikadatta, Gopikrishna, and Datta, 2014).

The absence of clear reporting and guidelines data for in vitro trials can be evidenced in this review, through the risk of bias analysis was performed. Research protocols such as, sample size, specimens allocation, blinding and operator details were not considered or were not described by the authors in mostly of the studies thus, compromising the quality of some outcomes (Hammel et alii., 2022).

Further studies are needed to clarify the influence of some variables such as load values and load application angle for mechanical testing, the adhesive strategy, fiber dimensions, and amount of remaining tooth structure on the mechanical behavior of restoration with composite fiber-reinforced in extensive posterior tooth cavities

V - CONCLUSION

This systematic review and study protocol was registered in PROSPERO database under code CRD42023425509 and followed the PRISMA guidelines. The search question applied to this work was: *Does the restoring of posterior teeth with fiber-reinforced composites shows fracture resistance values similar to those of healthy posterior teeth or, of non-fiber-reinforced composite restorations, or of unrestored extensive cavity preparations?*

According to the analysis performed it is possible to state the following conclusions:

- From 932 possible relevant articles obtained, only 24 publications met the inclusion criteria, of which 23 had moderate and one high risk of bias.
- Overall fracture resistance of fiber-reinforced composite restorations median value was of 976.0 N and differ from all control groups.
- Fracture resistance median value of tooth with fiber-reinforced composite restorations was higher than those of tooth with non-fiber-reinforced composite restoration (771.0 N; $p=0.008$) and tooth with unrestored cavity preparations (386.6 N; $p<0.001$), but lower than healthy tooth (1459.9; $p=0.048$).
- Qualitative analysis of the 24 in vitro studies reviewed showed variability regarding the materials (fibers type, composition and position, for the direct resin composites filler composition and clinical consistency, for other types of resin composites, for number of specimens included in the tested and the control groups) and, the in vitro protocols (posterior, premolar and/or molar teeth, the strain rate of the compressive load, the cell diameter of the testing device and the specimens thermocycling procedures).

Within the limitation of absence of clear reporting and guidelines data for in vitro trial, it can be concluded that posterior teeth restored with fiber-reinforced composites have improved fracture resistance behavior when compared to equivalent teeth restored with composites, but the fracture resistance of the composite/fiber combination is not similar to that of the healthy tooth. Based on the studies reviewed, resin-based composite with fiber-reinforced is an appropriate direct restorative alternative approach for coronal restorations of posterior teeth with extensive cavities in high stress intra-oral locations, by improving mechanical behavior of the restored tooth. But, clinical outcomes are needed to support, or not, those in vitro findings.

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ANNEXE

ANNEX I

Figure 1 - Registration of systematic review and study protocol in the International Prospective Register of Systematic Reviews (PROSPERO) database.

PROSPERO acknowledgement of receipt [425509]

Dear Registrant,

Thank you for submitting details of your systematic review for registration in PROSPERO.

We will check the information supplied to

- make sure that your systematic review is within scope
- ensure that the fields have been completed appropriately.

These checks do not constitute peer review or imply approval of the systematic review methods.

Processing of UK/NIHR-funded records and records related to COVID-19 are currently being prioritised and are usually registered within 3-5 working days.

All other records that have been waiting more than 10 days for registration will be automatically processed. During this time you may continue working on your review.

Due to technical issues, you will not be notified by email if your record is automatically published. Instead, please check your account after 10 days to confirm registration. If your application is rejected we will advise you of the reasons for non-publication (usually this will be if your review is out of scope).

Whilst the record is being processed, it will be locked and you will not be able to access it.

If you feel that you or members of your review team would benefit from additional training in systematic review methods, prior to commencing your review, we would recommend considering the 'Introduction to systematic reviews course' run by the Centre for Reviews and Dissemination at the University of York.

https://www.york.ac.uk/crd/training-services/introduction-to-systematic-reviews/

Yours sincerely,
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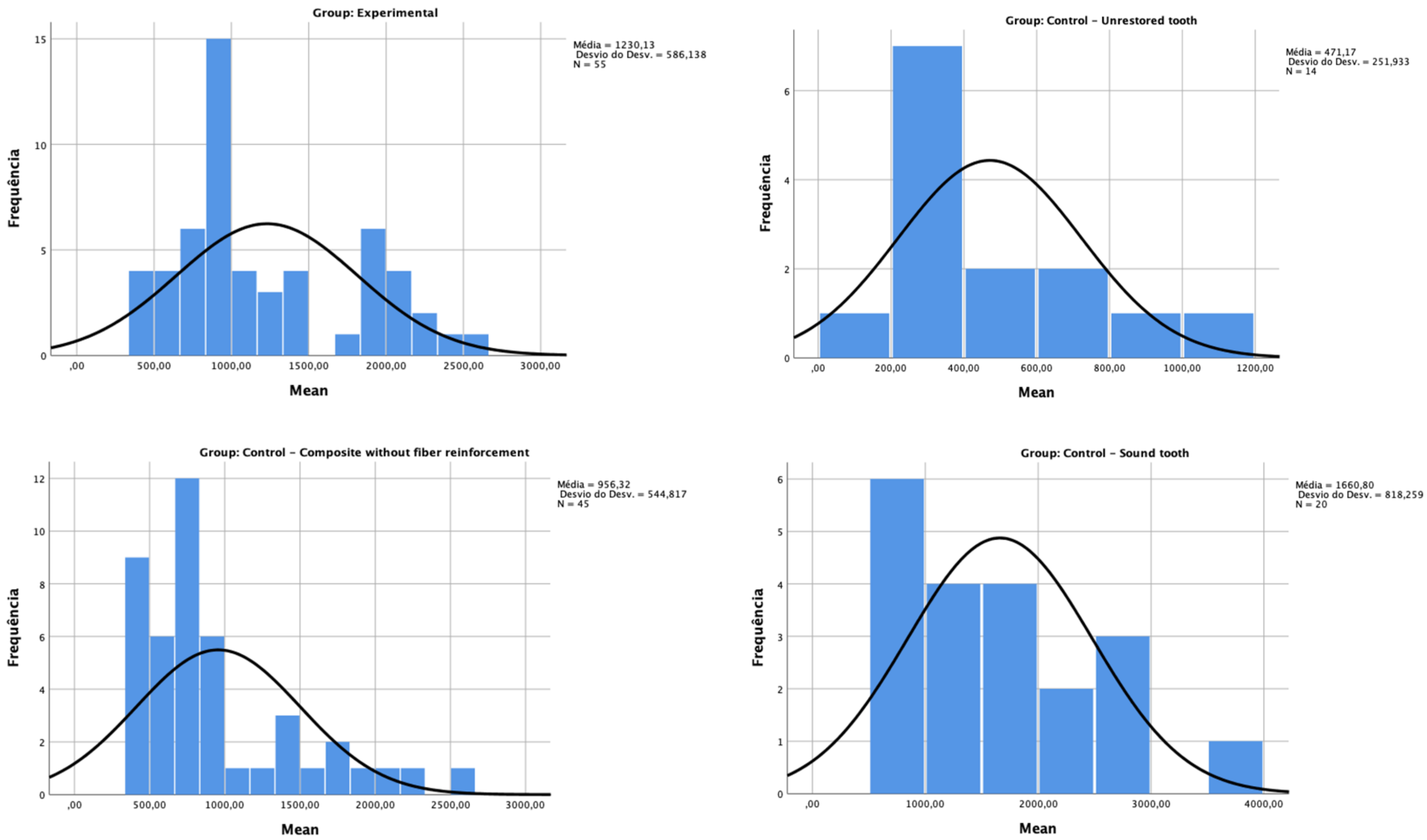
ANNEX II

Figure 3 - Histograms and normality curves of the analyzed groups.



ANNEX III

Figure 4 - Comparison of fracture resistance values between experimental and several control groups. Kruskal-Wallis test Pairwise method.