ORIGINAL RESEARCH

Fracture Resistance of Two Preparation Designs on Anterior Laminate Veneers: A Systematic Review and Meta-analysis

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Abstract

Aim: This systematic review aims to assess the fracture strength of two different types of tooth preparation designs for ceramic veneers and establish whether there is any association between the preparation performed and the type of failure observed.

Background: This systematic review literature search was undertaken in the databases MEDLINE Ovid (from 1946), Scopus, and Google Scholar, as well as a hand search of the references of included publications. *Ex vivo* and *in vitro* studies were included. The risk of bias was assessed. Meta-analysis was performed comparing palatal chamfer and butt joint preparation using fracture resistance as an outcome.

Review results: A total of 11 studies were included for systematic review and the meta-analysis included 10 studies of relatively high quality.

Conclusions: Within the limitations of the current study, it can be concluded that the failure risk of the palatal chamfer and butt joint preparation veneers revealed no statistically significant difference, but further studies are required for validation.

Clinical significance: Debonding is the most frequent complication and is found to be associated with lithium disilicate and zirconia restorations. The evidence seems to support the use of both butt joint and palatal chamfer incisal preparation design. In comparison with a specific type of material used for veneer (lithium disilicate and zirconia), the fracture strength of the tooth is unaffected by the palatal chamfer preparation made of, resulting in a lesser risk of failure in ceramic veneers compared to butt joint.

Keywords: Butt joint preparation, Chamfer preparation, Fracture resistance, Laminate veneer, Tooth preparation designs, Veneers.

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Introduction

Porcelain veneer restorations have grown more predictable in dental practice since its introduction in the late 1930s because of advancements in porcelain.[1,2] For many years, full-coverage crown restorations or direct composite veneers have provided the best predictable and long-lasting results for treating cosmetic corrections.[3,4] Full-coverage restoration is more invasive, requiring considerable amounts of tooth structure to be removed, as well as the possibility of deleterious effects on the adjacent pulp and periodontal tissues.[5] With the advancement of adhesive systems and the development of newer generation ceramic technology, the use of laminate veneers has been a reliable and frequently used treatment modality,[6] which is regarded as the most recommended, biocompatible, and conservative approach for meeting a patient's cosmetic needs while causing the least amount of damage to tooth structures[7,8] and are widely indicated for the restoration of discolored, worn, malformed, or crown-fractured teeth.[9] However, there is no clinical consensus on the sort of design chosen for anterior laminate veneers. Overlap and nonoverlap are the two basic forms of incisal preparation. The window (or intraenamel), the feather edge, the palatal chamfer (or overlapping), and the butt joint (or incisal bevel) are the four frequent incisal preparations. The nonoverlap classification includes the window and feathered-edge preparation, whereas the overlap classification includes the butt joint and palatal chamfer preparation.[10,11]

Fracture, microleakage, and debonding are the three most common reasons for porcelain veneer failure. The stress distribution and fracture strength of laminate veneers with various preparation designs have been examined. One study reported that after a 15-year observational period of clinical performance of corresponding restorations, fractures accounted for 67% of overall failures.[12] Concerning ceramic veneers strength, one study stated that it must be exposed to minimal occlusal loads[5] and this was supported by Toh et al.[1] revealing that, ceramic veneers are specified primarily in restoring esthetics rather than function. Anyhow, Friedman[13] stated that ceramic veneers can provide suitable esthetics as well as predictable functional strength.

Concerning preparations with or without incisal coverage, many studies reported advantages of overlap preparation over nonoverlap preparation. One study demonstrated that the cohesive fracture of laminate veneers primarily affected the incisal edge of the restoration due to an increase in stress.[8] There were studies depicting that stress concentration was decreased with incisal edge reduction[14,15] as well as that the adhesion and the retention surface area of the restoration increases in overlapped incisal edge preparation.[13] The incisal overlap is generally recommended as the

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incisal reduction can improve the translucency of veneers[16] and tolerates greater occlusal loading[17] which gives greater longevity in the long term, as they present a uniform distribution of stresses in relation to the protrusion movement, thus inserting a mechanical resistance to fracture.[4]

Bevel or butt joint (with incisal coverage) takes advantage in the control over the incisive esthetics and has easy cementation, and as a disadvantage, it is less retentive. Overlap preparation (palatal chamfer) as an advantage, it avoids the buccal displacement of the part, but it presents the disadvantage of a greater reduction of dental structure.[11] However, the failure risk between butt joint and palatal overlap type is unknown, as some observational studies found that the overlap type had a higher survival rate than the butt joint type,[18,19] while other research found the opposite.[20,21]

Few researchers have looked at how the preparation design affects the restoration's success and longevity. It is still up for debate whether the various tooth preparation designs may have an impact on the fracture strength of ceramic veneers or if one configuration is better than the other. Veneers with butt joint and overlap types are also being discussed for their survival or success rates. In general, it showed that there will be no difference between these preparation designs. However, some studies found that the overlap type had a higher survival rate than the butt joint type[18,20] whereas a recent systematic review evaluated the relationship between preparation designs and porcelain veneer prognosis, and found that either type was successful, with incisal coverage being associated with a higher but statistically insignificant risk of failure.[22] However, the failure risk among butt joint and overlap designs remains unknown.

The purpose of this systematic review is to compare how veneers from two different preparation designs differ in terms of survival and success. Thus, this systematic review and meta-analysis concentrated on the impact of preparation designs on the load to fracture of veneer restorations. The research question was: is palatal chamfer design (I) more resistant to fracture (O) than butt joint design (C) on anterior laminate veneers (P)?

Materials and Methods

This systematic review was conducted in accordance with the PRISMA reporting guidelines. The systematic review has been registered in PROSPERO database (CRD42021251710). The systematic review and meta-analysis included *in vitro* and *ex vivo* studies done on anterior teeth. It was limited to *in vitro* and *ex vivo* studies as fracture resistance could be measured only through such study designs. Teeth free of caries, cracks, and fractures were included. Butt joint preparation design as the control group and palatal chamfer preparation design as the intervention group. The outcome measured was fracture resistance measured in terms of load to fracture (in Newton) using a universal testing machine.

Literature Search

The electronic search strategy was conducted with the databases MEDLINE Ovid, Scopus, Google Scholar, and EBSCO**.** The review included only trials that were published in the English language and there were no restrictions instituted on the date and country of publication. The search strategies for the databases were modeled on that designed for MEDLINE Ovid. Further, the reference lists of the studies that were included were also searched for further references, and hand searching of studies was also tried.

Search Strategy

The search strategy was [Anterior OR Incisor OR Veneer OR Porcelain OR (Dental esthetics)] AND [(butt joint) OR (Shoulder Joint) OR (butt Preparation) OR (Preparation Design) OR (Incisal butt) OR (Incisal Preparation) OR (finish line)] AND [Palatal OR Chamfer OR (Incisal Edge)] AND [Fracture OR Failure OR (Fracture Resistance) OR (Load to Failure) OR (Fracture Strength)].

Study Selection

The obtained articles were imported to Covidence and the process of screening was completed. Two authors (BT and AJ) individually excluded further duplicates from the collected results and the relevant articles were examined by title and abstract. The studies had inclusion criteria as (a) *In vitro* studies determining the comparison of two or more incisal preparation designs; (b) Restrictions were placed on the type of tooth selected, only anterior teeth were selected, studies that were in English language with full-text articles, studies that measured fracture resistance in Newton's (N) or other units that could be converted to Newton's were selected. The exclusion criteria were (a) Incisal preparation design with no clear description; (b) Acrylic or composite veneers and clinical case reports. Further inclusion/exclusion was obtained and analyzed from the full text. Those studies were excluded whose inclusion criteria were not attained. After the title and abstract were screened, the complete text of those articles was examined. In case of any conflicts, a third review author (PS) was consulted in order to reach consensus. The search was conducted from 27th April 2021 for PubMed and 5th May 2021 for Scopus databases mentioned. For the analyzed time frame, there was no lower limit.

Data Extraction

For each study that is included, the extracted details were tabulated by two reviewers (BT and AJ) using Microsoft Excel sheet, including the participant study definition, country, study design, type of material, luting cement, type of preparation design, sample size, loading angle, outcome measure, outcome assessment method, and results of the intervention and control groups. Mean differences (MDs) and standard deviations were used to summarize the treatment effect for each research. Data were analyzed with RevMan 5.4.1.

Quality Assessment

Two reviewers (BT and AJ) assessed the bias risk independently. There was no standardized tool available for assessing bias risk for *in vitro* studies. Previous studies have used customized tools. The present study also used a customized tool adapted from a study.[23] The following parameters were assessed and graded for calculating the risk of bias:

- Presence of control group
- Description of sample size calculation
- Veneer preparation performed by a single operator
- Standardization of universal testing machine
- Procedures following manufacturer's instructions
- Blinding of outcome assessor.

The article received a Y (yes) for that definite parameter if the writers stated it; if the data could not be found, the article received an N (no). The studies that stated 1–2 items were categorized as high risk of bias, 3–4 as medium risk, and 5–6 as low risk.

Measures of Treatment Effect

Statistical Analysis

The data were analyzed using RevMan 5.4.1 version software developed by the Cochrane group. A meta-analysis was performed if the data were available from the studies which had similar comparisons and outcomes. Random effect model was used to develop statistical analysis as there were methodological variations in the included studies. For continuous data (fracture load) the mean and standard deviation were compared and summary measure was MD. The fracture resistance (primary outcome) of two preparation design results were the effect. Maximum fracture load was recorded in Newton. Quantitative synthesis was performed and since fracture resistance measures were obtained using a standard measurement (universal testing machine), the MD was estimated among the intervention and control group. For any missing data, the study was excluded from the review. Statistical heterogeneity of the treatment effect among studies was assessed by Cochrane's Q statistic, a Chi-square test, and a *p*-value cut-off of less than 0.10 to estimate the data's heterogeneity.[24] The I^2 statistic and forest plots were used to assess the consistency of the results.[25] In comparison to sampling error, the I^2 statistic describes the proportion of variation in point estimates related to heterogeneity.

Subgroup Analysis and Investigation of Heterogeneity

Due to variations in the methodology, subgroup analysis was done. Fracture was subgrouped according to (i) type of material used for fabrication of veneer (leucite-based, lithium-based, or zirconia) and (ii) based on angle of load applied (90 and 135°).

Results

Search Results

The search strategy identified a total of 312 articles, out of which 201 articles were included for title and abstract screening after the duplicate studies were removed. Of which, 163 articles were excluded as they were irrelevant. There were 38 articles left after reading the titles and abstracts which were reviewed in full and submitted to the relevance test, 11[26–36] studies were included for qualitative synthesis. Finally, 10[26–35] articles were selected for quantitative synthesis. All the studies were conducted *in vitro* with sample size ranging from 5 to 20 in numbers. The article selection process has been summarized in Flowchart 1 in the form of a flowchart according to the PRISMA statement.

Out of the 11 studies included, three were from India,[27,30,35] three from Egypt,[29,31,34] two from US,[28,32] one study from Germany,[33] one from North Macedonia,[36] and one from Lebanon.[26] Out of the 27 articles excluded, the outcome assessed varied in 12 studies,[17,37–47] six articles used different intervention group,[48–53] five articles used wrong study design,[4,54–57] two articles used wrong patient population,[20,58] one article used wrong study setting,[59] and remaining one article used different comparator group.[60] A total of 11 studies were able to fulfill all of the selection criteria and were taken up in this systematic review. Essam et al.'s[29] study is considered as two studies Essam a and Essam b as it demonstrated the fracture resistance of palatal chamfer and butt joint preparations in two different materials. The contributions of each study in this systematic review are presented in Table 1.

Descriptive Analysis

In 10 studies, universal testing machine was used to determine fracture loads[26–34,36] whereas in one study it was not specified.[35] Among the 11 studies, fracture load was recorded in Newton in eight studies[26,27,29,31–35] while it was recorded in kgF[28] and kgN[30] in one study each, which was converted to Newton. One study[36] did not specify the unit of force applied and thus it was not included for meta-analysis. Leucite (IPS Empress) was material of intervention group for five studies,[27,28,32,33,35] zirconia for three studies,[29,31,34] lithium disilicate (IPS e.max) for two studies,[26,29] and feldspathic for two studies.[30,36]

In five studies, load was applied at an angle of 135° in accord with the orthognathic interincisal angle.[26,27,29,30,34] Other three studies have loaded them at 90° angle, this is where the stresses that affect maxillary veneers during mastication and protrusive excursions are directed.[28,31,32] In one study, veneers were loaded at 0° in a direction parallel to the long axis of the tooth in order to study the result of the vertical component of incising force.[33] In one study, it was loaded at 45°[36] and in the other study it was not specified.[35] Six studies presented results related to both fracture strength and mode of failure.[26–28,32,33,35] Three studies presented

Flowchart 1: PRISMA flowchart

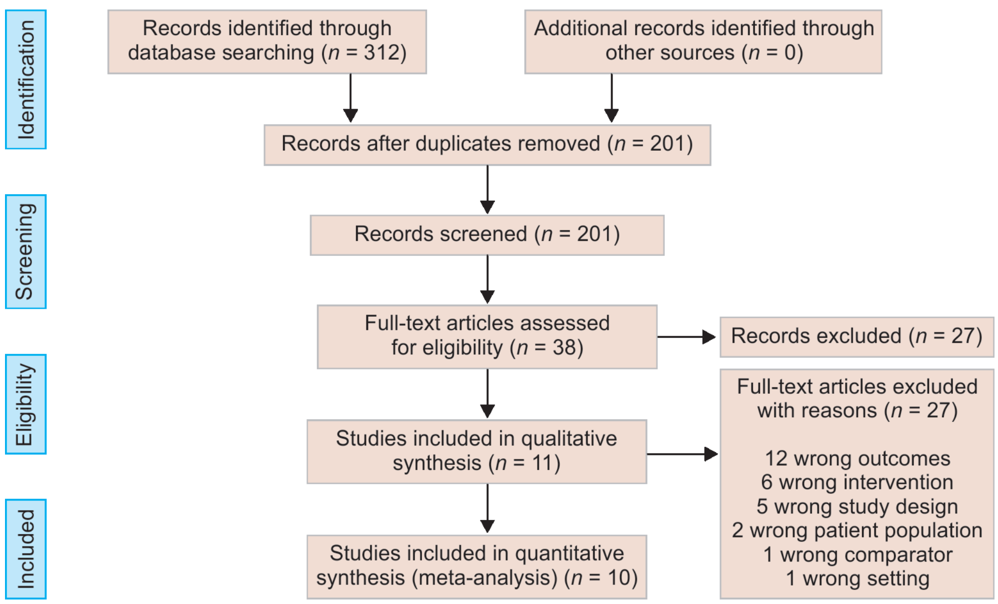


Table 1: Demographic and study design of included study

Study	*Country of study*	*Type of sample*	*Type of material*	*Cement*	*Intervention*	*Incisal reduction*	*Control group*	*Incisal reduction*	*Outcome measured*	*Mode of fracture*	*Angle*	*Unit*
Altabal et al. (2015)[26]	Lebanon	Anterior tooth	IPS e.max	Resin cement	Palatal chamfer	2 mm	Butt joint	2 mm	Universal testing machine	Adhesive failure, cohesive failure, root fracture	135°	Newton
Arora et al. (2017)[27]	India	Anterior tooth	IPS Empress	Resin cement	Palatal chamfer	2 mm	Butt joint	2 mm	Universal testing machine	Coronal fracture, cervical fracture, root fracture, total fracture	125°	Newton
Castelnuovo et al. (2000)[28]	US	Anterior tooth	IPS Empress	Resin cement	Palatal chamfer	1 mm	Butt joint	2 mm	Universal testing machine	Coronal fracture, cervical fracture, root fracture	90°	Newton
Essam a (2017)[29]	Egypt	Anterior tooth	Zirconia	Resin cement	Palatal chamfer	2 mm	Butt joint	2 mm	Universal testing machine		135°	Newton
Essam b (2017)[29]	Egypt	Anterior tooth	IPS e.max	Resin cement	Palatal chamfer	2 mm	Butt joint	2 mm	Universal testing machine		135°	Newton
Jankar et al. (2014)[30]	India	Anterior tooth	Feldspathic	Resin cement	Palatal chamfer	1 mm	Butt joint	1 mm	Universal testing machine		135°	Newton
Saker and Özcan (2021)[31]	Egypt	Anterior tooth	Zirconia	Resin cement	Palatal chamfer	1.5 mm	Butt joint	1.5 mm	Universal testing machine	Cohesive failure, adhesive failure, mixed failure, root fracture	90°	Newton
Schmidt et al. (2011)[32]	US	Anterior tooth	IPS Empress	Resin cement	Palatal chamfer	2 mm	Butt joint	2 mm	Universal testing machine	Type I: cohesive failure, type II: mixed failure, type III: adhesive failure, type IV: root fracture	90°	Newton
Stappert et al. (2005)[33]	Germany	Anterior tooth	IPS Empress	Resin cement	Palatal chamfer	3 mm	Butt joint	2 mm	Universal testing machine	Root fracture, cervical fracture, facial fracture, incisal fracture, longitudinal fracture	0°	Newton
Tamimi et al. (2017)[34]	Egypt	Anterior tooth	Zirconia	Resin cement	Palatal chamfer	2 mm	Butt joint	2 mm	Universal testing machine		135°	Newton
Vaidya et al. (2019)[35]	India	Anterior tooth	IPS Empress	Resin-modified glass ionomer	Palatal chamfer	1 mm	Butt joint	1 mm	Not specified	Incisal third, middle third, cervical third	Not specified	Newton
Zlatanovska et al. (2019)[36]	Republic of Macedonia	Anterior tooth	Feldspathic	Not specified	Palatal chamfer	Not specified	Butt joint	Not specified	Universal testing machine	Incisal, combined, gingival	45°	Not specified

results related to fracture strength.[29,30,34] One study presented results related to fracture strength, marginal discrepancy, and mode of failure[31] and one study presented results only as regards mode of failure.[36] Considering the intervention groups in these studies, palatal chamfer preparation design was the only intervention group in 11 studies[26–36] and butt joint preparation design was the only control group in 11 studies. The reduction varied from 0.3 to 0.5 mm on the facial surface, and from 1 to 3 mm on the incisal edge. Resin cement was the mainly used luting material in all studies.

Meta-analysis

The strength test was done in the *in vitro* trials used in this meta-analysis by applying an increasing static load. Total of 10 studies[26–35] with 84 samples compared the palatal chamfer with butt joint preparation, with regard to fracture strength. There was no statistically significant difference between the two preparation designs [(MD): 6.91 (–26.77, 40.59)] with significant heterogeneity across the studies $I^2 = 88\%$ (Fig. 1).

Total of three studies[29,31,34] with 20 samples and two studies[26,29] with 12 samples compared the fracture resistance of palatal chamfer with butt joint preparation with regard to zirconia-based material and lithium disilicate, respectively which demonstrated that there was a significant reduction in fracture strength when the tooth was prepared with palatal chamfer with a mean reduction of [MD: 48.92 (5.94, 91.91)] and [MD: 44.30 (21.75, 66.86)] when compared with butt joint preparation with significant heterogeneity across the studies $I^2 = 85\%$ and with an absence of heterogeneity $I^2 = 0\%$ correspondingly as may be observed from Figures 2A and B.

Study or Subgroup	Incisal chamfer Mean	SD	Total	Butt joint Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Altabal 2015	400.4	71.7	7	346.5	46	7	8.5%	53.90 [-9.21, 117.01]
Arora 2017	403.64	29.58	8	473.37	32.21	8	11.0%	-69.73 [-100.03, -39.43]
Castelnuovo 2000	160.83	33.73	10	268.71	94.44	10	8.5%	-107.88 [-170.03, -45.73]
Essam 2017 a	395	37.18	5	324.9	28.49	5	10.2%	70.10 [29.04, 111.16]
Essam 2017 b	365.4	17.65	5	322.5	21.15	5	11.3%	42.90 [18.75, 67.05]
Jankar 2014	930	96	5	898	107.6	5	4.5%	32.00 [-94.39, 158.39]
Saker 2021	560	22.3	10	548.6	28.6	10	11.4%	11.40 [-11.08, 33.88]
Schimdt 2011	166.67	28.89	8	131.84	18.88	8	11.3%	34.83 [10.91, 58.75]
Stappert 2005	533.1	242.3	16	598.2	290.8	16	2.6%	-65.10 [-250.57, 120.37]
Tamimi 2017	394.95	16.82	5	324.94	25.11	5	11.2%	70.01 [43.52, 96.50]
Vaidya 2019	143.5	39.81	5	202.4	39.46	5	9.6%	-58.90 [-108.03, -9.77]
Total (95% CI)			**84**			**84**	**100.0%**	**6.91 [-26.77, 40,59]**

Heterogeneity: $Tau^2 = 2457.06$; $Chi^2 = 86.68$, df = 10 ($p < 0.00001$); $I^2 = 88\%$
Test for overall effect: Z = 0.40 ($p = 0.69$)

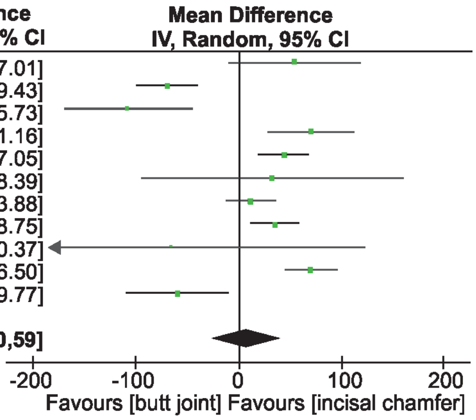
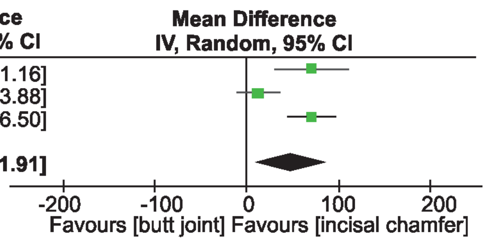


Fig. 1: Comparison of fracture resistance of butt joint and palatal chamfer design

Study or Subgroup	Incisal chamfer Mean	SD	Total	Butt joint Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Essam 2017 a	395	37.18	5	324.9	28.49	5	29.3%	70.10 [29.04, 111.16]
Saker 2021	560	22.3	10	548.6	28.6	10	36.0%	11.40 [-11.08, 33.88]
Tomimi 2017	394.95	16.82	5	324.94	25.11	5	34.7%	70.01 [43.52, 96.50]
Total (95% CI)			**20**			**20**	**100.0%**	**48.92 [5.94, 91.91]**

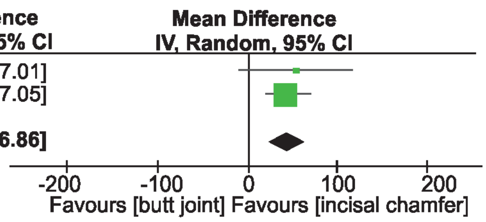
Heterogeneity: $Tau^2 = 1203.84$; $Chi^2 = 13.20$, df = 2 ($p = 0.001$); $I^2 = 85\%$
Test for overall effect: Z = 2.23 ($p = 0.03$)



A

Study or Subgroup	Incisal chamfer Mean	SD	Total	Butt joint Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Altabal 2015	400.4	71.7	7	346.5	46	7	12.8%	53.90 [-9.21, 117.01]
Essam 2017 b	365.4	17.65	5	322.5	21.15	5	87.2%	42.90 [18.75, 67.05]
Total (95% CI)			**12**			**12**	**100.0%**	**44.30 [21.75, 66.86]**

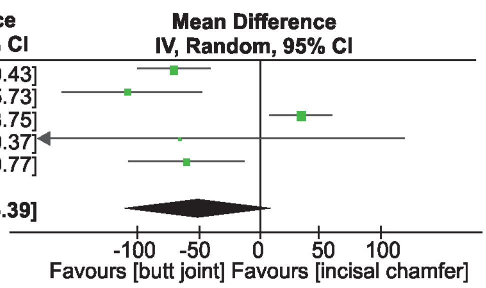
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.10$, df = 1 ($p = 0.75$); $I^2 = 0\%$
Test for overall effect: Z = 3.85 ($p = 0.0001$)



B

Study or Subgroup	Incisal chamfer Mean	SD	Total	Butt joint Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Arora 2017	403.64	29.58	8	473.37	32.21	8	24.2%	-69.73 [-100.03, -39.43]
Castelnuovo 2000	160.83	33.73	10	268.71	94.44	10	20.7%	-107.88 [-170.03, -45.73]
Schimdt 2011	166.67	28.89	8	131.84	18.88	8	24.7%	34.83 [10.91, 58.75]
Stappert 2005	533.1	242.3	16	598.2	290.8	16	8.2%	-65.10 [-250.57, 120.37]
Vaidya 2019	143.5	39.81	5	202.4	39.46	5	22.3%	-58.90 [-108.03, -9.77]
Total (95% CI)			**47**			**47**	**100.0%**	**-48.99 [-113.38, 15.39]**

Heterogeneity: $Tau^2 = 4219.80$; $Chi^2 = 40.85$, df = 4 ($p = <0.00001$); $I^2 = 90\%$
Test for overall effect: Z = 1.49 ($p = 0.14$)



C

Figs 2A to C: (A) Comparison of fracture resistance of butt joint and palatal chamfer design of zirconia-based ceramic veneers; (B) Comparison of fracture resistance of butt joint and palatal chamfer design of lithium disilicate-based ceramic veneers; (C) Comparison of fracture resistance of butt joint and palatal chamfer design of leucite-based ceramic veneers

In contrast, a total of five studies[27,28,32,33,35] with 47 samples compared the fracture resistance of palatal chamfer with butt joint preparation, with regard to fabricated material (leucite). The studies presented results without significant differences with regard to fracture strength compared to palatal chamfer and butt joint preparations [MD: –48.99 (–113.38, 15.39)] with significant heterogeneity across the studies $I^2 = 90\%$ (Fig. 2C).

Total of five studies[26,27,29,30,34] with 35 samples compared the fracture resistance of palatal chamfer with butt joint preparation with regard to load applied at 135°, no significant difference was observed between the two preparations [MD: 32.41 (–19.14, 83.96)] with significant heterogeneity across the studies $I^2 = 91\%$ (Fig. 3A).

Total of three studies[28,31,32] with 28 samples compared the fracture resistance of palatal chamfer with butt joint preparation with regard to load applied at 90°. There was no statistically significant difference between the two preparations [MD: –10.76 (–63.94, 42.43)] with significant heterogeneity across the studies $I^2 = 89\%$ (Fig. 3B).

A total of 10 studies[26–35] were considered for the overlap and butt joint type comparison. The failure risk of the overlap type was not significantly different from the butt joint type, according to the analysis of pooled estimates. However, the combined results of all studies revealed that the risk of failure was unrelated to the type of preparation with butt joint and palatal chamfer. This could probably be due to the small number of studies and high heterogeneity.

In the subgroup analysis of porcelain materials, we found three studies involving zirconia[29,31,34] and two studies[26,29] involving lithium disilicate indicating a statistically significant association between failure risk and preparation type with incisal coverage. Veneers with butt joint preparation had a higher failure rate than those with palatal chamfer. Similarly, when fracture resistance of ceramic veneers with butt joint and palatal chamfer preparation was divided based on load applied, the study involving maxillary anteriors revealed no statistical difference between fracture resistance of ceramic veneers with butt joint and palatal chamfer preparation under functional loads of 135 and 90°.

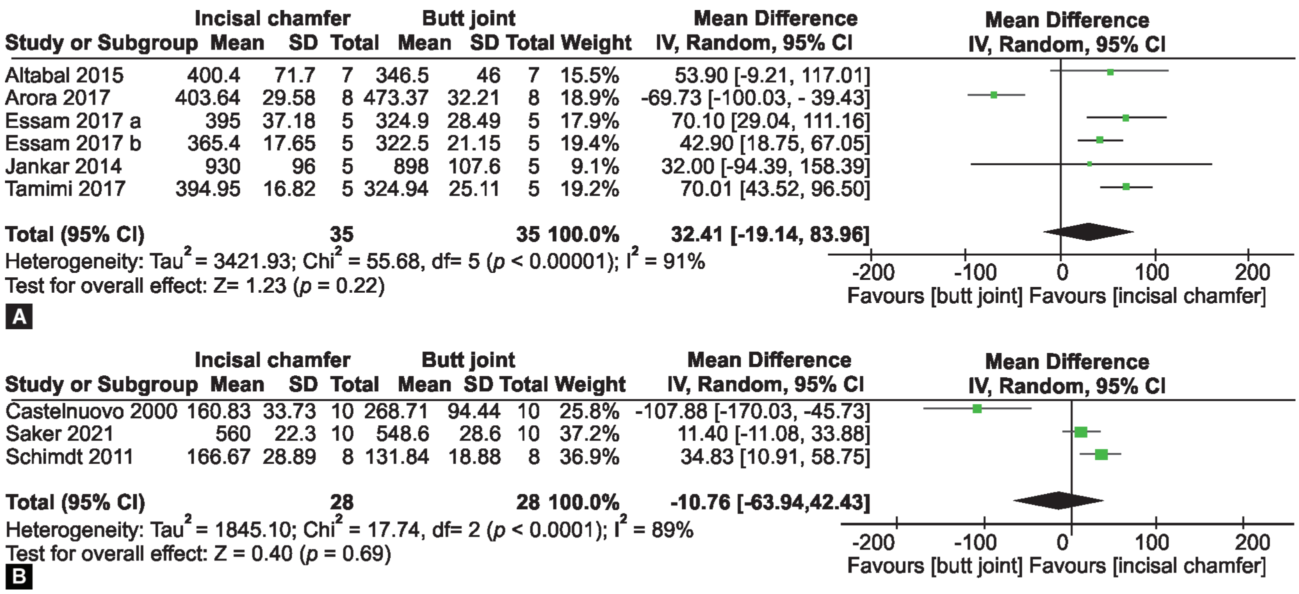
Quality Assessment

Quality assessment was done for included studies using a customized tool. It was found that all the studies had the presence of a control group, and no study reported a description of sample size estimation. One study out of 10 studies was carried out by a single operator. All the 10 studies performed the procedures following manufacturer's instructions. Nine out of 10 studies measured outcomes using universal testing machine. Within the 10 studies, around eight studies had moderate risk. One study[26] had low risk and two studies[35,36] was found to be of high risk (Table 2).

Discussion

Present day esthetic demands encourage patients to seek dental care for esthetic quality and harmonious smiles. It is the responsibility of dentists to understand the expectations of patients, and to develop a treatment plan that fits their indications. Among the various restorations for esthetic purposes, ceramic laminates stand out for presenting color stability, high strength and durability, excellent surface smoothness, abrasion resistance, and low accumulation of bacterial plaque.[61] The fracture resistance of ceramic veneers was important to long-term clinical success. Various studies have been shown in the past to assess the fracture resistance of ceramic veneer with different types of preparation, but none has compared the fracture resistance of two different preparation designs.

An updated systematic review and meta-analysis was conducted to compare the fracture resistance of two different anterior veneer preparation design; butt joint and palatal chamfer type using results from *in vitro* and *ex vivo* studies. The review was limited to including only *in vitro* and *ex vivo* studies as fracture resistance could be measured numerically only through these designs. Clinical studies were very few where success/failure of the veneer was considered as the outcome. Different types of porcelain veneer preparation designs have been documented and compared. The study's conclusions are varied and occasionally contradicting and did not allow for a conclusion to be made on the most appropriate preparation strategy. A total of 10 studies[26–35] were appropriate to



Figs 3A and B: (A) Comparison of fracture resistance of butt joint and palatal chamfer design with regard to load applied at 135°; (B) Comparison of fracture resistance of butt joint and palatal chamfer design with regard to load applied at 90°

Table 2: Risk of bias assessment

Study	*Presence of control group*	*Description of sample size calculation*	*Veneer preparation performed by a single operator*	*Standardization of universal testing machine*	*Procedures following manufacturer's instructions*	*Blinding of outcome assessor*	*Overall risk of bias*
Altabal et al. (2015)[26]	Yes	No	Yes	Yes	Yes	No	Low
Arora et al. (2017)[27]	Yes	No	No	Yes	Yes	No	Medium
Castelnuovo et al. (2000)[28]	Yes	No	No	Yes	Yes	No	Medium
Essam et al. (2017)[29]	Yes	No	No	Yes	Yes	No	Medium
Jankar et al. (2014)[30]	Yes	No	No	Yes	Yes	No	Medium
Saker and Özcan (2021)[31]	Yes	No	No	Yes	Yes	No	Medium
Schmidt et al. (2011)[32]	Yes	No	No	Yes	Yes	No	Medium
Stappert et al. (2005)[33]	Yes	No	Yes	Yes	Yes	No	Medium
Tamimi et al. (2017)[34]	Yes	No	No	Yes	Yes	No	Medium
Vaidya et al. (2019)[35]	Yes	No	No	No	Yes	No	High
Zlatanovska et al. (2019)[36]	Yes	No	No	Yes	No	No	High

the palatal chamfer preparation and butt joint preparation to assess the effect of tooth preparation design on load to failure of laminate veneers. One study[36] was not included due to the difference in methodology restricting its inclusion in this meta-analysis. The analysis of the pooled results revealed insignificant results [MD: −4.93 (−39.47, 29.62)], specifying there is no difference between the failure risk of the palatal chamfer preparation compared to the butt joint preparation. The inconsistency test showed that characteristic heterogeneity occurred between these 10 studies. A total of five studies[26,29,30,32,34] revealed that the risk of failure was greater along with the butt joint preparation compared to palatal chamfer preparation. For the determination of incisal edge reduction for laminate veneer preparation, the results of these studies advise the palatal chamfer preparation. These studies results were also supported by Chaiyabutr et al.[39] showing that the palatal chamfer preparation has superior mechanical and adhesive qualities over butt joint preparation. Reasoning of these studies with more favorable results for the palatal chamfer preparation design is that the ceramic located in the palatal chamfer area has been explored as providing stability to the veneer in opposition to the movements it is exposed to on the vestibular surface during the application of force[39] and that the cement layer absorbs the stress from the area.[14] Another rationale for the palatal chamfer preparation's favorable outcomes is that the palatal extension, in addition to widening the bond surface, also gives higher longitudinal exposure of the enamel prisms, thereby enhancing bond quality.[32] However, in contrast, a meta-analysis of *in vitro* studies by Da Costa et al.[62] concluded that even though there was no statistical variance in ceramic fractures among both the preparations, the butt joint incisal preparation may have increased advantages compared with the palatal chamfer regarding ceramic fracture and incidence of tooth fracture.

Among 10 studies reviewed for meta-analysis, five studies[27,28,31,33,35] showed that the strength of the tooth was least affected by the butt joint design. Saker and Özcan[31] revealed that when compared to the palatal chamfer preparation, the butt joint preparation revealed increased fracture resistance, although the difference was not statistically significant. The conclusion of this study was validated by Castelnuovo et al.[28] documented that the butt joint preparation had the maximum resistance to fracture compared to palatal chamfer preparation. The reason attributed was by loading directly across the palatal finish line, resulting in a greater fracture risk for the thin palatal chamfer preparation. The outcomes of these studies were also supported by Stappert et al.[33] implying that the better the adhesion of ceramic veneers to the dental structure, the less wear there is on the tooth structure with a higher exposure of enamel, indicating longer durability. The study by Arora et al.[27] and Vaidya et al.[35] concluded based on the result of their studies that the butt joint is the most effective preparation for ceramic veneers if incisal coverage is desired. Additionally, Guess et al.[18] demonstrated veneers with butt joint preparation signified a slightly better survival rate compared that with palatal chamfer. A number of factors favored butt joint preparation over palatal chamfer preparation, according to these studies; it was easier to prepare, had a faciopalatal path of insertion, had greater fracture strength, had a low risk of initiating a fracture of thin unsupported palatal ceramic ledges, had improved esthetics at the incisal one-third of veneers, had favorable bonding to exposed enamel prisms and easier identification of the finish line on the model, among other benefits.[28] Nevertheless, the comparison of the failure risk between palatal chamfer type and butt joint type stays unclear since the number of studies is limited and incomprehensive heterogeneity.

The samples of two studies[33,35] taken in this meta-analysis were subjected to thermocycling, with the purpose of decreasing the inconsistency between the clinic and laboratory. Stappert et al.[33] reported less number of veneers fractured during initial cyclic loading. This result was supported by Bergoli et al.[37] whereas Chaiyabutr et al.[39] demonstrated the failure of all veneers under 100,000 cycles, respectively. These contrasting study results suggest that fatigue testing for laminate veneers is varied depending on frequency of loading, magnitude, distance, direction as well as the quality of sample teeth.

To examine differences in the outcomes with respect to the porcelain materials and the load applied, subgroup analyses were performed. For veneer preparation, feldspathic ceramic, lithium disilicate, fluorapatite, and lithium silicate reinforced with zirconia are being used currently.[22] The clinical indications of distinct classes of dental ceramics are determined by the composition, microstructure, and characteristics of ceramic materials. Though, toughness and strength, and to a lesser extent elastic modulus and hardness, regulate fracture in ceramics.[63] Subgroup analysis regarding the porcelain materials, three studies[29,31,34] involving zirconia laminate veneers and two studies[26,29] involving lithium disilicate laminate veneers demonstrated a statistically significant relation between preparation type and failure risk. This increased risk of failure was related to veneers with butt joint preparation compared to palatal chamfer. The maximum principal stress in these two materials is lower, and the stress distribution in the cement layer is more uniform.[29] In contrast, we recognized five studies[27,28,32,33,35] involving leucite laminate veneers reporting that when comparing the teeth preparation, there were no significant changes in fracture strength. The inconsistency test showed evident heterogeneity among the studies ($I^2 = 90\%$). Although analyses were incomplete due to the inadequate number of included studies, the present study revealed that the palatal chamfer preparation with zirconia and lithium disilicate veneers had the lowest fracture risk.

The studies included in this subgroup analysis used different angulations during the loading tests for the application of force. According to Gibbs et al.[64] during functional actions like chewing and swallowing, the intercuspal position is critical. The forces created in this posture are the largest and strongest, whereas the forces created during eccentric contacts during functional movements are relatively moderate and short-acting. As the ceramic materials are more prone to fracture when subjected to tensile stresses, the studies that were submitted to this meta-analysis used various angulations for applying force during loading tests. In accordance with orthognathic interincisal angle at 135°, five studies[26,27,29,30,34] compared the fracture resistance of two preparations by loading the tooth-veneer system at this angle. To assess the horizontal constituent of load applied on the palatal surface of maxillary incisors by mandibular incisors, three studies[28,31,32] loaded veneer samples at a 90° angle to the long axis of the tooth structure. Furthermore, this angle avoids sliding of the Instron crosshead on the sample's palatal area.[65] Though, neither of the subgroup analyses concerning the load applied, yielded statistically significant outcomes. Few studies compared failure risks by loading the tooth-veneer system parallel to the long axis of the tooth at the incisal edge.[33] The results of these studies suggest that the fracture resistance of ceramic veneers is regardless of the precise direction of load applied. However, it is identified that the palatal concavity, on the other hand, is known to be the location where stress forces are concentrated. Magne[66] clearly demonstrated that teeth restored with veneers can stimulate the performance of intact teeth, resulting in a comparable stress distribution pattern. It is strongly associated with composition and it is not dependent on the specific direction of load applied. In contrast, the results of Arora et al.[27] found that the fracture resistance of ceramic veneers under functional stresses was higher at 125° than at 60° for both butt joint and palatal chamfer design. Patients who have parafunctional habits and inauspicious inclination of teeth present a higher increase in angulations and the magnitude of force. In this case, according to Ustun and Ozturk[46] the butt joint preparation presented a more advantageous geometry for stress distribution than palatal chamfer as it has a high clinical success rate, shows more constant stress distribution in the cement layer, and lower maximum principal stress.

Studies involving enamel preparations with 0.5 mm depth were included in this meta-analysis, as it provides optimum veneer thickness and bonding ability for clinical use.[65] On the other hand, with the improvements in the properties of adhesive systems, it is not a major concern to perform minimal preparation that is restricted to enamel only and some researchers have observed no difference between enamel-only preparation and involving dentine preparations.[20] Natural teeth were employed in this study to provide a more clinically relevant substrate in terms of preparation design, bonding process, cementation, and other factors, which may have an impact on the load to fracture except in one study.[35] Majority of the articles in the review demonstrated the mode of failure of laminate veneers with butt joint and palatal chamfer preparation. Adhesive, mixed, cohesive, and root fracture modes were observed in three studies.[26,31,32] Altabal et al.[26] reported the majority of fractures observed were adhesive in both preparations ($n = 3$; 50%), and also reported a suggestively greater number of root fractures ($n = 3$; 50%) in the incidence of failure with butt joint preparation than in palatal chamfer ($n = 1$; 16.7%). Saker and Özcan[31] reported that the butt joint and palatal chamfer group showed higher prevalence to adhesive failure ($n = 4$; 40%) in both preparations with veneer fractures. In both groups, the incidence of root fracture was similar. In contrast to above two studies, Schmidt et al.[32] demonstrated higher prevalence to cohesive failure with veneer fractures in palatal chamfer ($n = 7$; 87%) and butt joint ($n = 5$; 62%) preparations.

Stappert et al.[33] showed the modes of fracture in terms of root fracture, cervical fracture, facial fracture, incisal fracture, and longitudinal fracture and found that among these, the majority of fractures were root fractures in which palatal chamfer ($n = 16$; 81.25%) reported higher prevalence compared to butt joint preparation ($n = 16$; 31.25%). Castelnuovo et al.[28] reported a significantly more number of coronal fractures in both preparations ($n = 5$; 50%), and also reported a larger number of root fractures in butt joint preparation ($n = 4$; 40%) than palatal chamfer ($n = 2$; 20%) in the incidence of failure modality. Arora et al.[27] reported more coronal fracture in butt joint preparation ($n = 13$; 81.25%) than in palatal chamfer preparation ($n = 10$; 62.50%) whereas cervical fracture was found to be more in palatal chamfer ($n = 2$; 25%) than in butt joint preparation ($n = 4$; 12.50%). Vaidya et al.[35] reported oblique, incisal, middle, and cervical third fracture patterns. In both preparations, the fracture pattern examination revealed a higher number of middle-third fractures. Zlatanovska et al.[36] reported statistically significant dependence between the localization of the occurred changes (incisal, gingival, and combination) in both preparations. The most prevalent fracture localization in butt joint preparation is mixed ($n = 15$; 53.6%), followed by incisal ($n = 10$; 35.7%) and gingival ($n = 3$; 10.7 %). The combined and gingival localizations of the fracture are equally reported in palatal chamfer ($n = 4$; 14.3%), although, incisal is the most common localization ($n = 21$; 72.4%).

The failure pattern demonstrated a higher percentage of adhesive failures than cohesive in all study groups showing that bonding to restoration is still challenging. Difference in adhesion resin, maintenance condition, preparation processes, and kind of porcelain employed in each study differed could explain the disparity in failure mode. It is indicated that the most important factor in reducing compressive and tensile stresses in the veneer was the veneer's adherence and the technique of luting a veneer using resin cement necessitates competence on the part of the practitioner, as correct moisture management and management of the resin cement are critical.[45] Both dual-curing and light-curing cement could be used for adhesive luting of porcelain veneers. Light-activated resin cement is commonly used to cement ceramic veneers because they have a longer working time, which makes it easier to remove excess and increase color stability.[67] The adhesive resin is protected by a close fit between the restorative margins and the tooth structure from the repeated exposure to oral fluids as a result of the reduction in the process of progressive chemical, mechanical, and physical disintegration qualities that cause recurring deterioration, microleakage, and other problems as well as the development of stress concentrations.[6,68] So establishing an adequate marginal fit in laminate veneers is very important. Some studies demonstrated tooth fracture[27,28,33] and the possible reason could be variation in the elastic modulus of the teeth following extraction and storage.[33,69] This study's findings are based on *in vitro* studies, therefore they can be cautiously applied to the oral (*in vivo*) environment. In the oral environment, a porcelain laminate is exposed to a variety of chemothermal variables, including fast pH changes, hot and cold liquids, mechanical forces, and pulp pressure. Although *in vivo* tests are the most accurate way to assess the performance of laminate veneer, the presence of so many variables makes it impossible to pinpoint the underlying cause of failure.

According to the failure mode analysis, for lithium disilicate and zirconia restorations, debonding is the most common cause of failure, whereas cohesive fracture of the veneering porcelain is the most common cause of failure for leucite-based restorations. The frequency of root fracture observed when butt joint type of design was used and butt joint preparation did not differ significantly from the frequency of adhesive, cohesive, and coronal fracture found in palatal chamfer.

There are certain limitations to this review. There are only limited included articles available in the literature with regard to comparison of preparation designs. One of the foremost arguments of these studies is the standardization and application of suitable testing conditions. It is important to note that a restoration's mechanical performance in the oral environment is not only influenced by its resistance to forces exerted on it. In spite of its drawbacks, static load-to-failure testing enables easy test standardization, an overview of the fracture behavior of a tooth restoration complex, material strength comparisons, failure risk estimate, data collection, and study comparison. The strength test was done in the *in vitro* trials used in this meta-analysis by applying an increasing static load. Subgroup analyses were used in our systematic review to account for variation among included research.

Finally, we recognized that 10 studies specified that both types of incisal preparation designs of laminate veneers could be considered strong enough to withstand anterior forces. We recommend further clinical studies with failure rates as outcome to analyze the real-world experience of the effect of veneer preparation designs.

Conclusion

The fracture resistance of teeth with the butt joint preparation was not significantly different from that of teeth made with the palatal chamfer preparation. The fracture resistance of teeth prepared with both types was similar to one another. Under functional loads of 135 and 90°, fracture resistance of ceramic veneers with butt joint and palatal chamfer preparation showed no statistical difference. There was no statistical difference in the mode of failures in laminate veneers between the palatal chamfer and butt joint preparation designs. Lithium disilicate and zirconia laminate veneers show statistically significant association between preparation types that increased risk of failure was related to veneers with butt joint preparation compared to palatal chamfer. The most common cause of failure. Debonding is the most common cause of failure for lithium disilicate and zirconia restorations. So material selection, manufacturing technique, and restoration design all have a role in the success of ceramic restorations.

Clinical Relevance

The evidence seems to support the use of both butt joint and palatal chamfer incisal preparation design. Debonding is the most frequent complication and is found to be associated with lithium disilicate and zirconia restorations. In comparison with specific type of material used for veneer (lithium disilicate and zirconia), the fracture strength of the tooth is unaffected by the palatal chamfer preparation made of, resulting in a lesser risk of failure in ceramic veneers compared to butt joint.

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