Frontiers in Dentistry

Effect of Preparation Design on Marginal Integrity and Fracture Resistance of Endocrowns: A Systematic Review

Azam Sadat Mostafavi[1,2], Somayeh Allahyari[1,2], Somayeh Niakan[1,2], Faezeh Atri[1,2*]

1. Department of Prosthodontics, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran
2. Dental Research Center, Dentistry Research Institute, Tehran University of Medical Sciences, Tehran, Iran

Article Info

Article type:
Systematic Review

Article History:
Received: 28 Mar 2022
Accepted: 25 Oct 2022
Published: 27 Nov 2022

**** Corresponding author:***
Dental Research Center, Dentistry Research Institute, Tehran University of Medical Sciences, Tehran, Iran

Email: f-atri@sina.tums.ac.ir

ABSTRACT

Objectives: Endocrown restorations were introduced for endodontically treated teeth as a conservative treatment. However, data about the effect of preparation design on marginal integrity and fracture resistance of endocrowns are lacking. The purpose of this systematic review was to investigate the effect of preparation design of endocrown restorations on marginal integrity and fracture resistance.

Materials and Methods: Based on PICO question and the search terms, PubMed, Embase, Scopus, and the Cochrane Library were searched. After including studies matched to predefined inclusion and exclusion criteria, the extracted data were tabulated in a table provided by the authors. Two reviewers assessed the methodological quality of each included study independently. Ten articles were selected for extracting the quantitative data. All included studies were in vitro. The potential risk of bias of the selected studies was assessed using the modified MINORS scale.

Results: Four studies assessed the marginal adaptation, five studies evaluated the fracture resistance and just one investigated both the marginal integrity and fatigue resistance of the specimens. The evaluated influencing items in preparation design were as follows: cavity depth, occlusal thickness, ferrule effect, internal divergence angle, type of finish line, and adding vents inside pulp chamber. Meta-analysis could not be done due to heterogeneity of preparation designs and evaluation methods.

Conclusion: Marginal discrepancy of endocrowns is intensified with adding preparation features, higher cavity depth and increasing the divergence. Fracture resistance of endocrowns is increased with more occlusal reduction and cavity depth. However, it is still beyond the normal clinical force range.

Keywords: Crowns; Tooth Preparation, Prosthodontic; Flexural Strength; Dental Marginal Adaptation

➢ **Cite this article as:** Mostafavi AS, Allahyari S, Niakan S, Atri F. Effect of Preparation Design on Marginal Integrity and Fracture Resistance of Endocrowns: A Systematic Review. *Front Dent.* 2022:19:37.

INTRODUCTION

Ceramic endocrown restorations are proposed instead of conventional post-and-core and crowns in some endodontically treated posterior teeth [1]. Its durability and success rate has been reported same or more than post-and-core and crown with the advantages of conservative preparation, adhesive retention mechanism, less clinical and laboratory sessions and possibility of use in teeth without ferrule [2]. Endodontically treated teeth have been shown to be weaker due to extensively loss of structure. Their fracture resistance decreases with extending the occlusal cavity and involving marginal ridges in preparation [3]. Ceramics with proper mechanical properties and adhesive capacity are good choice for inlay, onlay and endocrown restorations [4]. Based on literatures, marginal adaptation and fracture strength are introduced as the important factors for the survival and success of prosthetic restorations [5,6].

Copyright © 2022 The Authors. Published by Tehran University of Medical Sciences.
This work is published as an open access article distributed under the terms of the Creative Commons Attribution 4.0 License (http://creativecommons.org/licenses/by-nc/4). Non-commercial uses of the work are permitted, provided the original work is properly cited.

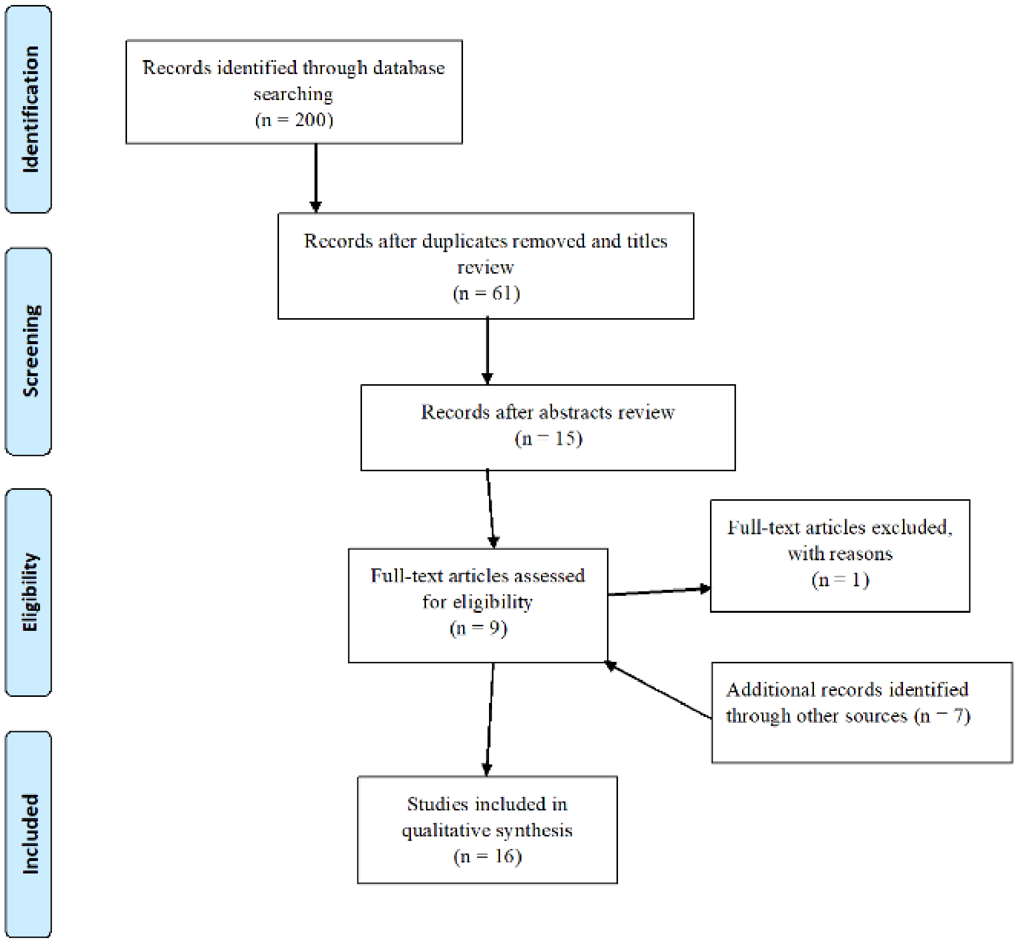

Fig. 1. Decision tree of systematic literature review

Lack of marginal integrity leads to caries, periodontal disease, marginal discoloration and loss of cementation [7]. Factors affecting the marginal integrity are amount of remaining enamel and dentin, type of impression or scanning, cementation process, bulk and type of materials and preparation design. On the other hand, fracture strength of ceramic restoration is depended on remaining tooth structure, bulk and type of materials and preparation design [3,4]. The influence of preparation design of ceramic inlay and onlay on clinical performance of vital teeth has been studied but little data are available about endodontically restored teeth with endocrowns [8]. In reviewing the preparation design for endocrown, important items include: occlusal reduction, type of finish line, cavity depth, internal divergence, presence of ferrule and intra radicular extension. Principal preparation for endocrown has been suggested as following: 2 to 3mm cuspal reduction, butt joint finish line, round internal angles, 6-degree divergence of pulpal walls, even pulpal floor with sealed radicular orifice, and supragingival enamel margins if possible[9]. However, in some cases the typical preparation could not be performed and some modifications are needed [10-12]. Because of different variables that are influential, there was a need for a review on this subject. The purpose of this systematic review was to investigate literatures, which have dealt with the effect of preparation design in endocrown restorations on marginal integrity and fracture resistance.

MATERIAL AND METHODS

The present systematic review was implemented in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines [13]. The search question was: Does specific preparation design effect on marginal integrity and fracture resistance of endocrowns? The PICO was in the following order: the population was posterior teeth with endocrown restoration; the intervention was preparation design; and the outcomes were marginal integrity and fracture resistance.

Search strategies

An electronic search in PubMed, Embase, Scopus, and the Cochrane Library was performed till 2021 February by two independent authors (AS.M, S.A). (Fig. 1) The search terms were as follows: (Dental Restoration, Permanent OR Ceramics OR Endocrown OR Endo*crown OR Tooth, Nonvital OR Endodontically treated teeth OR Inlays OR onlay OR Partial (coverage OR crown) OR zirconium oxide OR yttria stabilized tetragonal zirconia OR Felspathic OR Lithium disilicate OR Empress OR E max OR E*max OR Computer-aided design OR CAD/CAM OR computer aided OR Zirconia OR zirconium OR ZR OR Y-TZP) AND (Tooth preparation OR Cavity (depth Or length) OR Endocrown length OR Palpal extension OR (Intracoronal OR preparation) depth OR Taper OR Divergency OR Ferrule OR Finishline OR Finish*line) AND (Dental Marginal Adaptation OR Marginal (fit OR gap OR discrepancy OR integrity OR accuracy) OR Clinical performance OR (Fracture OR fatigue) resistance OR Failure mode). All relevant clinical and in vitro studies were included. No randomized clinical studies published in the English language dental literature evaluating effect of preparation design of endocrowns on the criteria are listed in Table 1.

Table 1: Eligibility criteria

Inclusion Criteria	Exclusion Criteria
Studies evaluating endo crown	Studies on post-core crown, conventional crown or onlay in vital teeth
Studies in English	Case reports
Clinical and in vitro studies	Reviews
Materials used: ceramic	Materials used: composite
	Finite elements

selected outcomes were identified. The eligibility After the identification of articles in the mentioned databases, the articles were imported into Endnote X9 software (Thompson Reuters, Philadelphia, PA, USA) to remove duplicates.

Study selection

The titles and abstracts of the included studies were evaluated independently by 2 investigators (F.A, S.N.). Afterwards, the full text of the articles (for the selected abstracts) were reviewed and matched to predefined inclusion and exclusion criteria. In addition, if there were insufficient data in the title and abstract, the pertinent full text was considered for analysis by all authors. Furthermore, the manual search was performed through the references of the selected articles, and any articles found were reviewed for possible inclusion. Any disagreement was resolved by discussion and consensus between authors. The obtained information was registered by authors for data extraction.

Data extraction

The data were extracted from the included articles according to Table 2, containing the following items: authors, year, type of study, test groups, number of specimens, type of specimens, restoration material, internal taper, impression method, evaluation method, spacer thickness, finish line, cement type, preparation depth, and result.

Quality assessment

Two reviewers independently examined the methodological quality of each included study based on the following items: clear statement of aim, contemporary groups, baseline equivalence of groups, specimen randomization, method of preparation, impression, and evaluation (gap/strength), examiner blinding, definitive restoration, sample size calculation, power analysis, and sufficient statistical analyses. For scoring, the items received a score of 0 when not reported; 1 when inadequately reported; and 2 when adequately reported. The overall score was set at 22 for each study and the risk of bias of the papers were categorized as high, medium and low based on their obtained score.

Table 2: Descriptive data of the included studies

References	Groups	Specimen type	N	Restoration material	Internal taper	Finish line	Cement	Impression method	Evaluation method	Spacer thickness	Results
Gaintantzopoulou 2016 [14]	1) 2mm intracoronal extensions 2) 3mm intraradicular extensions 3) 4mm intraradicular extensions	Acrylic resin first lower right molars	12	Vita Enamic	8-10°	Butt joint	-	Cerec bluecam	Micro-XCT	0	Increasing the intraradicular extension of endocown restorations increased the marginal and internal gap of endocrowns
Dartora 2018 [16]	1) 5mm extension 2) 3mm extension 3) 1mm extension. The GI cement was applied to the pulp chamber cavity	Lower molars	10	IPS e.max CAD	8-10°	Shoul-der	RelyX ARC	NR	Stereo-microscope ×10 & SEM	NR	Greater extension of endocrowns inside the pulp chamber provided better mechanical performance
Rocca 2018 [23]	1) Flat overlays with no endocore 2) 2mm extension 3) 4mm extension 4) control group: fiber post-crown	Upper first premolar	12	IPS e.max CAD	NR	Butt joint	Multilink Automix	Cerec Omnicam	Visually and stereo-microscope	NR	Endocrowns with 2mm and 4mm long endo-cores showed identical marginal integrity and fatigue resistance to classical crowns. Authors discouraged the use of flat overlays with only adhesive retention

Shin 2017 [15]	1) 2mm cavity depth 2) 4mm cavity depth	Lower first & second molars	24	IPS e.max CAD	10°	Shoul-der 1.5mm	Dual-poly-merized resin cement	Cerec bluecam, E4D	µCT scanning before and after cementation	30µm	Marginal and internal discrepancies increased depending on cavity depth
Taha 2017 [17]	B2: butt joint with 4mm extension. B3.5: butt joint with 2.5mm extension. S2: 1mm shoulder finish line with 2mm extension. S3.5: 1mm shoulder finish line with 2.5mm extension	Lower first molars	8	ENAMIC blocks	8°	Butt joint, shoul-der	RelyX Unicem2 Automix	Cerec bluecam	Visually and stereo-microscope ×10	NR	Adding a short axial wall and shoulder finish line can increase the fracture resistance
Darwish 2017 [22]	LS10: Lava, shallow depth (3mm), 10° LS6: Lava, 3mm, 6° LD10: Lava, extended depth (5mm), 10° LD6 : Lava, 5mm, 6° ES10: Emax, 3mm, 10° ES6: Emax, 3mm, 6° ED10: Emax, 5mm, 10° ED6: Emax, 5mm, 6°	Human bifurcated maxillary first premolars	5	IPS e.max CAD Lava Ultimate	6° or 10°	Butt joint	-	Cerec omnicam	CBCT scanner	80µm	Preparation with smaller axial wall divergence provides better internal fit. Central cavity depth is not influential on internal fit of endocrown restorations

Einhorn 2017 [18]	G0: without ferrule G1: 1mm ferrule G2: 2mm ferrule 2mm pulp chamber depth in all specimens	Lower third molars	12	IPS e.max CAD	NR	Butt joint for G0, NR for groups with ferrule	RelyX Unicem	Cerec	Fracture strength (static load at 45° to the long axis of the tooth)	NR	Ferrule containing preparations demonstrated significantly greater failure loads than standard endocrown restorations
Haralur 2020 [19]	1) 2mm occlusal reduction 2) 4.5mm occlusal reduction 3) 4.5mm occlusal reduction with 2mm radicular extension With three materials: (1) Lithium disilicate (2) Polymer infiltrated ceramic (3) High translucency zirconia	Lower molar teeth	10	IPS e.max Press; Vita Enamic); Ceramill Zolid HT	8°	Butt joint	RelyX Unicem2	Laboratory scanner (Ceramill Map, Amann Girrbach AG, Koblach, Austria)	Thermal cyclings and maximum static load at fracture	NR	Increased occlusal thickness showed improvement in fracture strength of lithium disilicate and polymer infiltrated ceramic molar endocrowns. The 2mm radicular extension in high translucent zirconia resulted in more unfavorable failure types

Ghoul 2020 [20]	Conventional: circumferential butt margin 2mm above the CEJ Modified: by adding 2 grooves on the mesial side of the vestibular dentinal wall and on the distal side of the lingual dentinal wall	Human lower molars	20	IPS e.max CAD	NR	Butt joint	G-CEM LinkForce	Intraoral scanner (TRIOS 3; 3 Shape A/S, Germany)	Thermomechanical cyclin, fracture strength in axial and lateral loading	NR	Modified endocrown design showed higher fracture resistance. Lateral loading displayed a high percentage of severe fracture but under higher load for normal masticatory forces
Topkara 2021 [21]	ManE: mandibular endocrown ModManE: modified mandibular endocrown with vents MaxE: maxillary endocrown; ModMaxE: modified maxillary endocrown with vents	Upper and lower molars	10	CEREC Blocs; Dentsply Sirona	NR	Butt margin	Maxcem Elite; Kerr Corp	Intraoral scanner (CEREC Omnicam; Dentsply Sirona)	Micro-computed tomo-graphy (µCT)	120µm	Internal and marginal adaptation of endocrowns differ between maxillary and mandibular molars

Abo-Elmagd 2015 [26]	Group 1: A glass fiber post and resin core and all-ceramic crown with shoulder finish line as control group. Group2: Endocrown with butt margin. Group3: Endocrown with 1mm wide and 2mm axial wall heights shoulder finish line	Lower premolars	5	IPS E-max press	8-10 degrees	Butt margin shoul-der finish line	Variolink N, Ivoclar Vivadent	Poly-vinyl siloxane impression material	Thermal cyclings and direct vision under digital microscope	NR	Endocrown margin design had no significant effect on vertical marginal gap
Alamin 2019 [25]	1) 2mm ferrule and deep chamfer finish line 2) butt joint margin	Human maxillary molars	30	Vita suprinity CAD/CAM	10 degree	Deep cham-fer, butt joint margin	Rylex U200	Optical scanner (dental wings 3series GmbH, Germany)	Thermal cycling and Fracture Strength (static compres-sive load)	NR	There was no statistically significant difference between tested groups

Haralur 2020 [9]	2mm occlusal reduction, 4.5mm occlusal reduction and 4.5mm occlusal reduction with 2mm radicular extension from three materials: Lithium Disilicate, Polymer infiltrated ceramic (PIC) and High translucency zirconia (HTZ)	Intact premolar teeth	10	IPS Emax, Ceramill Zolid HT Vita Enamic,	8 taper	Butt margin	RelyX Unicem2 Automix	Direct fabrication on teeth in LD group, laboratory scanner (Ceramil Map, Amann Girrbach AG, Koblach, Austria) in PIC and HTZ	Thermal cycling and Fracture Strength (static compres-sive load)	NR	The greater extension of endocrowns inside the pulp chamber and radicular extension provided better mechanical performance in LD ceramic and HTZ ceramics
Hayes 2017 [24]	Endocrown Chamber Extension Depth (mm): 2, 3, and 4mm from the occlusal table	Lower third molars	12	IPS e.Max CAD	NR	Butt margin	Rely-X Unicem	Cerec AC/Cerec MC XL, Sirona Dental Systems, Charlotte, NC, USA	Fracture Strength (static compres-sive load)	NR	All the groups displayed great fracture resistance than normal values of masticatory function and a high number of catastrophic fractures

Kuijper 2020 [12]	1- Control 2- Enamel outline 0 3- Enamel outline 2mm 4- Enamel outline 4mm 5- Dentin outline 0 6- Dentin outline 2mm 7- Dentin outline 4mm	Third molars	15	IPS e. max CAD	NR	Butt margin	Optibond FL Adhesive	Digital impression Cerec Omnicam; Sirona Dental Systems	Thermome chanical aging, fracture test	NR	The type of outline did no significantly influence the load to fracture. There was no difference between groups concerning mode of failure
Lise 2017 [27]	2.5mm-deep endocrown 5mm-deep endocrown 5mm-deep post & crown from; Composite - lithium disilicate glass ceramic	Single-rooted premolars	8	Cerasmart, GC IPS e.max CAD	5 degree	Butt margin	Clearfil Esthetic Cement	Chairside intraoral scanner Cerec Omnicam, Sirona	Cyclic loading and compres-sive fracture strength	50	All the groups withstood the chewing aging. Composite 2.5mm deep endocrown could withstand a significantly higher load-to failure, while the CAD/CAM material was not significant for other groups

RESULTS

Identification of studies

Among 200 studies from the initial search, 15 abstracts were selected for further evaluation. Nine full text articles were included after assessing the involved abstracts [2,14-21]. One study was excluded due to the specimens' type which were central theeth [2]. In addition, the references of the accepted articles were searched and 8 articles were added to the eligible full texts [9,12,22-27]. Therefore, 16 articles were selected for extracting the quantitative data [9,12,14-27]. The results of data extraction for each study are presented in Table 2. All included studies were in vitro.

Evaluation of risk of bias and quality of studies

There is no particular scale to determine the risk or the quality of the In vitro studies. Sometimes they may be reported as acceptable or unacceptable based on study design. In the present systematic review, two authors (AS.M/F.A) independently assessed the potential assessed risk of bias of the studies included using the modified MINORS scale, a methodological index for non-randomized studies [28]. The items were scored 0 if not reported; 1 when reported but inadequate; and 2 when reported and adequate. The global ideal score was 22; the authors considered low risk of bias when study's score was 15-22, medium risk of bias for 10-15 and high risk of bias for scores lower than 10. Consensus was reached by the two reviewers (AS.M/F.A) when there was discrepancy about one item. In case of no consensus, the independent opinion of a third reviewer was decisive (S.A). Since the included studies fulfilled the score for low risk of bias, all of them were retained in the review. (Table 3) The specimens of 7 studies were human mandibular molars [15-20,24], two studies used maxillary premolars [22,23] , one study maxillary molars [25], one study maxillary and mandibular [21] molars, one study mandibular [25] premolars, one study third molars [12], two study premolars [9,27], and in just one study, acrylic mandibular molars [14] were applied. Shin et al [15], Darwish et al [22], Gaintantzopoulou et al [14], Abo-Elmagd et al [26] and Topkara et al [21] assessed the marginal adaptation, Taha et al [17], Dartora et al[16] and Einhorn et al [18], Haralur et al [9], Haralur et al [19], Alamin et al [25], Hayes et al [24], de Kuijper et al [12], Lise et al [27] and Ghoul et al [20] evaluated the fracture resistance and Rocca et al [23] investigated both the marginal integrity and fatigue resistance of the specimens. The evaluated influencing items in preparation design were as follows: cavity depth, ferrule effect, internal divergence angle, finish line, and adding vents inside pulp chamber. Despite the low level of evidence of in vitro studies (which does not necessarily mean that the study is weak or has a poor methodology), most of the time the obtained information from them are essential for planning future clinical studies. We could not perform meta-analysis because of the heterogeneity of preparation types and evaluation methods.

DISCUSSION

The purpose of this systematic review was to evaluate the effect of different preparation designs of ceramic endocrowns on marginal integrity and fracture strength. The analysis of related articles showed that modification of preparation design is influential on marginal adaptation and fracture resistance. Endocrown as a conservative restoration is aimed to preserve tooth structure as much as possible and its preparation follows the concept of decay-orientated design [29] .On the other hand, as the retention mechanism of endocrown is based on bonding, the greater the extension of restoration, the greater the surface area provided for adhesion and, therefore, better transmission of masticatory forces to dental structures [16]. Analysis of related articles presents some preparation modifications including different occlusal thickness, type of finish line, degree of divergence and presence of ferrule, increasing cavity depth and intra radicular extension.

The effect of these modifications is discussed as follows.

Table 3: Authors' judgments about each risk of bias item for each included in vitro study

	Clearly stated aim	Contemporary groups	Baseline equivalence of groups	Randomization of specimens	Preparation method	Impression method	Definitive restoration	Evaluation method (gap / strength)	Blinding of the examiner	Sample size calculation and power analysis	Adequate statistical analyses	Total score	Risk of bias
Dartora 2018 [16]	2	2	2	2	2	0	2	2	0	0	2	16	Low
Shin 2017 [15]	2	2	2	2	2	2	2	2	0	0	2	18	Low
Taha 2017 [17]	2	2	2	2	2	2	2	2	0	0	2	18	Low
Rocca 2018 [23]	2	2	2	2	2	2	2	2	0	0	2	18	Low
Darwish 2017 [22]	2	2	2	0	2	2	2	2	0	0	2	16	Low
Einhorn 2017 [18]	2	2	2	2	2	2	2	2	0	0	2	18	Low
Gaintantzopoulou 2016 [14]	2	2	2	0	2	2	2	2	0	2	2	18	Low
Haralur 2020[19]	2	2	2	2	2	2	2	2	0	2	2	20	Low
Ghoul 2020 [20]	2	2	2	0	2	2	2	2	0	0	2	16	Low
Topkara 2021 [21]	2	2	2	0	2	2	2	2	0	0	2	16	Low
Abo-Elmagd 2015 [26]	2	2	2	0	2	2	2	2	0	0	2	16	Low
Alamin 2019 [25]	2	2	2	2	2	2	2	2	0	0	2	18	Low
Haralur 2020 [9]	2	2	2	2	2	2	2	2	0	2	2	20	Low
Hayes 2017 [24]	2	2	2	2	2	2	2	2	0	0	2	18	Low
Kuijper 2020 [12]	2	2	2	2	2	2	2	2	0	0	2	18	Low
Lise 2017 [27]	2	2	2	2	2	2	2	2	0	0	2	18	Low

Cavity depth and intra-radicular extension

Some studies evaluated different endocrown preparation depth, with the assumption of deeper pulpal cavity provide more surface for bonding and better load transmission [30]. In addition, the radicular extension results in restoration stabilization during cementation in extensively destroyed teeth [14]. Contrarily, some confirmed that the increase in cavity depth of endocrown leads to significant increase in marginal discrepancy [14,15] and others revealed non-significant difference [22,23]. Although, Gaintantzopoulou et al. showed intraradicular extension of endocrown resulted in more marginal and internal gap and had a negative effect on its adaptation, it was in acceptable clinical range (less than 120 micron) [14]. Difference in results could be due to using different teeth (molars vs premolars), materials, measuring techniques and selected locations on the teeth. Higher marginal gap in deep cavities could be related to technical limitation of digital impression and CAD/CAM milling.

In terms of fracture resistance, Darota et al concluded that endocrowns with greater intra pulpal extension provided higher mechanical properties, better load transmission and lower intensity with fracture pattern of various compression curls, which is due to greater material resistance and prevention of fracture progress [16]. In case of less extension, lower fracture resistance and higher probability of restoration rotation during function was observed [16]. In this regard, decreased contact between endocrown and remaining tooth structure would be the reason, also the pattern of fracture was a uniform total tear of tooth fragments with remaining fewer dental tissue. However, fracture resistance of all samples was beyond the normal force on molar sites (850 N) [16]. Hayes et al showed deeper extension into the pulp chamber (4mm instead of 2mm) increases bonding surfaces and load to failure values, however inserted lateral loading to the cervical area running to more non-restorable fractures [24]. Therefore, it does not seem necessary to extend the preparation design in order to increase the strength, especially considering that the extension would increase the marginal discrepancy. On the other hand, Rocca et al reported no difference in fatigue resistance of endocrowns with two pulpal depth of 2 and 4 mm in comparison with conventional crowns and failures in all groups, were non-reparable (under CEJ) [23]. The recent result corroborates with the surveys of Kuijper et al [12] and Lise et al [27] in this regard. In addition, Haralur et al suggested not to use radicular extension due to predominantly unfavorable failures notably in ceramic specimens [9].

Occlusal thickness

The recommended occlusal thickness for endocrown is 2mm, [10] but there is controversy in literature regarding the effect of occlusal thickness on the fracture resistance. According to Otto et al [31], by increasing occlusal thicknesses, fracture load values increase, while Zhu et al recommend 1.5 mm thickness to prevent the bulk fracture [32]. Taha et al reported that endocrowns with various occlusal thicknesses withstood loads more than clinical situation (850N in molar); however, increasing the occlusal thickness of restoration resulted in higher fracture resistance with non-significant difference. Also, they revealed severe fracture of tooth and endocrown in all specimens [17]. Therefore, aggressive preparation to increase the occlusal thickness of the endocrown more than the standard is not suggested. In Harular et al study, the material type was shown to be influential on fracture resistance of endocrown restorations, so that Lithium disilicate demonstrated the maximum fracture resistance at 4.5 mm occlusal thickness; while Zirconia displayed better fracture resistance in 2 mm thickness [19]. On the other hand, tooth type (molar/premolar) have been shown to be influential in the obtained results [9]. One of the factors affecting occlusal reduction is thickness of remaining axial walls, as endodontically treated teeth need more than 3 mm thickness of walls for adhesive restorations. Therefore, reduction of narrow walls is inevitable [33]. Since occlusal thickness is in contrast with cavity depth, so the greater the occlusal damage, the lower available cavity depth, and the more difficult it to provide enough retention. Also, more occlusal thickness leads to lever arm forces, so in aggressive occlusal destruction, post and crown would be a better choice instead of endocrown.

Finish line: (shoulder/ butt joint)

The suggested classical finish line of endocrowns is butt joint (90-degree) to provide a flat surface and increase the strength against the compressive forces [34]. Shoulder finish line is also recommended because of an added short axial wall [34]. According to Taha et al study, higher fracture resistance was reported for shoulder finish line than butt joint, although the failure mode was the same in both finish lines. The authors suggested shoulder finish line because of better force distribution, decreasing load transmitted to pulpal floor, reducing resin cement thickness and consequently lower shrinkage polymerization and resultant stress applied to restoration [17]. Abo-Elmagd et al concluded that margin design has no significant effect on vertical marginal gap of endocrown restorations, however butt joint margin resulted in less marginal leakage than that with shoulder finish line using dye penetration technique [26]. In addition, Alamin et al demonstrated not significant effect of finishline design (shoulder or deep chamfer) in case of fracture resistance [25]. Considering the existed evidence and for preservation of coronal structure, butt joint finish line would be recommended as a simple and efficient margin design in endocrown restorations.

Divergence

Endocrown preparation is suggested to have 6-degree axial wall divergence instead of parallel walls, which prevent undercut formation and provide ease of seating. Increasing the amount of divergence more than standard may be unavoidable due to cavity figuration, but there are some concerns about the restoration fitness and retention [22]. Although, logically it is assumed that with increasing divergence, contact friction decreases and adaptation improves, but Darwish et al. reported that 6-degree axial wall divergence provides better internal fit that 10-degree divergence. They justified that the closer the geometry of the restoration to the geometry of the milling burs and the better internal fit [22]. Although the morphology of pulp chamber varies in different teeth, the modifications performed by dentists are also of great importance. According to Tobakara et al study, internal and marginal adaptation of endocrowns differ between maxillary and mandibular molars. Furthermore, it is suggested to provide 10-degree convergence in case of implementing ferrule in the preparation design [21].

Ferrule

Classical preparation of endocrown contains no ferrule and the suggested finish line is butt joint. It is minded that the addition of ferrule could increase fracture resistance and provide more surface for bonding. Using ferrule may improve bracing mechanism or negatively cause the loss of remaining enamel. Einhorn et al revealed that samples with 1- and 2-mm ferrule demonstrated higher fracture resistance than no ferrule. However, the values of failure stress based on available surface area for adhesive bonding was similar between the groups. Moreover, high percentage of catastrophic failures was reported in all groups (less common in specimens with 1mm ferule) under loads greater than normal clinical situation [18]. Considering ferrule in the preparation design should not destroy remaining enamel near the cementoenamel junction alternatively Also, in the absence of ferrule, preparing a short bevel can improve the bonding surfaces [35].

Adding internal features

It has been revealed that venting enhances the seating of the restorations [36]. According to Ghoul et al study, adding 2 grooves on dentinal walls of pulp chamber resulted in higher fracture resistance and a reduced stress concentration in comparison with conventional endocrown preparation design. Although most of the failures occurred in this group were severe but the applied loads were higher than the normal range of masticatory forces [20]. On the other hand, Tobkara et al presented that adding grooves had not significant affect the adaptation of the endocrown restorations [21].

Beside the effect of adding features on the fracture resistance, it should be considered that increasing the features in preparation may lead to difficulty in milling process, less adaptation of intaglio surface and weakening the remaining tooth structure due to excess removal of dentine [18].

Gathering these findings show that preparation design of endocrown can affect the fracture resistance and marginal integrity of the restoration. However, a systematic review of in vitro studies would not give a high level of evidence since its results could not be extrapolated to oral situation. Further investigations and especially clinical trials with long periods of follow-up are important to evaluate different modifications of endocrown preparation design on various criteria of success and survival of restoration such as marginal and internal adaptation, bonding strength, fracture resistance, aesthetic, ease of maintenance, and prevention of caries.

CONCLUSION

According to the findings of this systematic review, the following conclusions were drawn:

1) The preparation design of endocrown is influential on marginal adaptation and fracture resistance.

2) Fracture resistance of standard and modified endocrowns in terms of preparation design is beyond the normal masticatory force range, therefore excessive preparation (more occlusal reduction and cavity depth) in order to increase the fracture resistance is not recommended. Also, the type of fracture in standard and modified endocrowns is severe and non-repairable.

3) Marginal discrepancy of endocrowns is increased with adding preparation features, more cavity depth and increasing the divergence, so it is suggested to maintain the preparation as simple as cavity configuration lead.

CONFLICT OF INTEREST STATEMENT

None declared.

REFERENCES

1. Sedrez-Porto JA, Rosa WL, da Silva AF, Münchow EA, Pereira-Cenci T. Endocrown restorations: A systematic review and meta-analysis. J Dent. 2016 Sep;52:8-14.
2. Kanat-Ertürk B, Saridağ S, Köseler E, Helvacioğlu-Yiğit D, Avcu E, Yildiran-Avcu Y. Fracture strengths of endocrown restorations fabricated with different preparation depths and CAD/CAM materials. Dent Mater J. 2018 Mar 30;37(2):256-265.
3. Mincik J, Urban D, Timkova S, Urban R. Fracture Resistance of Endodontically Treated Maxillary Premolars Restored by Various Direct Filling Materials: An In Vitro Study. Int J Biomater. 2016;2016:9138945.
4. Kassem IA, Farrag IE, Zidan SM, ElGuindy JF, Elbasty RS. Marginal gap and fracture resistance of CAD/CAM ceramill COMP and cerasmart endocrowns for restoring endodontically treated molars bonded with two adhesive protocols: an in vitro study. Biomater Investig Dent. 2020 Feb 25;7(1):50-60.
5. Halawani SM, Amer Al-Harbi S. Marginal adaptation of fixed prosthodontics. IJMDC. 2017; 1(2): 78-84.
6. Rekow ED, Silva NR, Coelho PG, Zhang Y, Guess P, Thompson VP. Performance of dental ceramics: challenges for improvements. J Dent Res. 2011 Aug;90(8):937-52.
7. Soares CJ, Celiberto L, Dechichi P, Fonseca RB, Martins LR. Marginal integrity and microleakage of direct and indirect composite inlays: SEM and stereomicroscopic evaluation. Braz Oral Res. 2005 Oct-Dec;19(4):295-301.
8. Hopp CD, Land MF. Considerations for ceramic inlays in posterior teeth: a review. Clin Cosmet Investig Dent. 2013 Apr 18;5:21-32.
9. Haralur SB, Alamri AA, Alshehri SA, Alzahrani DS, Alfarsi M. Influence of Occlusal Thickness and Radicular Extension on the Fracture Resistance of Premolar Endocrowns from Different All-Ceramic Materials. App Sci. 2020;10(8):2696.
10. Elagra ME. Endocrown preparation: Review. Int J Appl Dent Sci 2019;5(1):253-256.
11. Ghajghouj O, Taşar-Faruk S. Evaluation of Fracture Resistance and Microleakage of Endocrowns with Different Intracoronal Depths and Restorative Materials Luted with Various Resin Cements. Materials (Basel). 2019 Aug 8;12(16):2528.
12. de Kuijper MCFM, Cune MS, Tromp Y, Gresnigt MMM. Cyclic loading and load to failure of lithium disilicate endocrowns: Influence of the

restoration extension in the pulp chamber and the enamel outline. J Mech Behav Biomed Mater. 2020 May;105:103670.
13. Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009 Jul 21;6(7):e1000097.
14. Gaintantzopoulou MD, El-Damanhoury HM. Effect of Preparation Depth on the Marginal and Internal Adaptation of Computer-aided Design/Computer-assisted Manufacture Endocrowns. Oper Dent. 2016 Nov/Dec;41(6):607-616.
15. Shin Y, Park S, Park JW, Kim KM, Park YB, Roh BD. Evaluation of the marginal and internal discrepancies of CAD-CAM endocrowns with different cavity depths: An in vitro study. J Prosthet Dent. 2017 Jan;117(1):109-115.
16. Dartora NR, de Conto Ferreira MB, Moris ICM, Brazão EH, Spazin AO, Sousa-Neto MD, et al. Effect of Intracoronal Depth of Teeth Restored with Endocrowns on Fracture Resistance: In Vitro and 3-dimensional Finite Element Analysis. J Endod. 2018 Jul;44(7):1179-1185.
17. Taha D, Spintzyk S, Schille C, Sabet A, Wahsh M, Salah T, et al. Fracture resistance and failure modes of polymer infiltrated ceramic endocrown restorations with variations in margin design and occlusal thickness. J Prosthodont Res. 2018 Jul;62(3):293-297.
18. Einhorn M, DuVall N, Wajdowicz M, Brewster J, Roberts H. Preparation Ferrule Design Effect on Endocrown Failure Resistance. J Prosthodont. 2019 Jan;28(1):e237-e242.
19. Haralur SB, Alamrey AA, Alshehri SA, Alzahrani DS, Alfarsi M. Effect of different preparation designs and all ceramic materials on fracture strength of molar endocrowns. J Appl Biomater Funct Mater. 2020 Jan-Dec;18:2280800020947329.
20. Ghoul WE, Özcan M, Tribst JPM, Salameh Z. Fracture resistance, failure mode and stress concentration in a modified endocrown design. Biomater Investig Dent. 2020 Aug 7;7(1):110-119.
21. Topkara C, Keleş A. Examining the adaptation of modified endocrowns prepared with CAD-CAM in maxillary and mandibular molars: A microcomputed tomography study. J Prosthet Dent. 2022 May;127(5):744-749.
22. Darwish HA, Morsi TS, El Dimeery AG. Internal fit of lithium disilicate and resin nano-ceramic endocrowns with different preparation designs. Future Dental Journal. 2017;3(2):67-72.
23. Rocca GT, Daher R, Saratti CM, Sedlacek R, Suchy T, Feilzer AJ, et al. Restoration of severely damaged endodontically treated premolars: The influence of the endo-core length on marginal integrity and fatigue resistance of lithium disilicate CAD-CAM ceramic endocrowns. J Dent. 2018 Jan;68:41-50.
24. Hayes A, Duvall N, Wajdowicz M, Roberts H. Effect of Endocrown Pulp Chamber Extension Depth on Molar Fracture Resistance. Oper Dent. 2017 May/Jun;42(3):327-334.
25. Sakrana A, Al-Zordk W, elameen A. Impact of Marginal Preparation Design on the Fracture Resistance of Endo-Crown All-Ceramic. IOSR Journal of Dental and Medical Sciences. 2019;18:11-7.
26. Abo-Elmagd A, Abdel-Aziz M. Influence of marginal preparation design on microleakage and marginal gap of endocrown cemented with adhesive resin cement. Dental Journal. 2015;61(5481):5489.
27. Pedrollo Lise D, Van Ende A, De Munck J, Umeda Suzuki TY, Cardoso Vieira LC, Van Meerbeek B. Biomechanical behavior of endodontically treated premolars using different preparation designs and CAD/CAM materials. J Dent. 2017 Apr;59:54-61.
28. Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, Chipponi J. Methodological index for non-randomized studies (minors): development and validation of a new instrument. ANZ J Surg. 2003 Sep;73(9):712-6.
29. Lander E, Dietschi D. Endocrowns: a clinical report. Quintessence Int. 2008 Feb;39(2):99-106.
30. Mörmann WH, Bindl A, Lüthy H, Rathke A. Effects of preparation and luting system on all-ceramic computer-generated crowns. Int J Prosthodont. 1998 Jul-Aug;11(4):333-9.
31. Otto T, Mörmann WH. Clinical performance of chairside CAD/CAM feldspathic ceramic posterior shoulder crowns and endocrowns up to 12 years. Int J Comput Dent. 2015;18(2):147-61.
32. Zhu J, Rong Q, Wang X, Gao X. Influence of remaining tooth structure and restorative material type on stress distribution in endodontically treated maxillary premolars: A finite element analysis. J Prosthet Dent. 2017 May;117(5):646-655.
33. Veneziani M. Posterior indirect adhesive restorations: updated indications and the Morphology Driven Preparation Technique. Int J Esthet Dent. 2017;12(2):204-230.
34. Fages M, Bennasar B. The endocrown: a different type of all-ceramic reconstruction for molars. J Can Dent Assoc. 2013;79:d140.
35. Govare N, Contrepois M. Endocrowns: A systematic review. J Prosthet Dent. 2020 Mar;123(3):411-418.e9.
36. Patel D, Invest JC, Tredwin CJ, Setchell DJ, Moles DR. An analysis of the effect of a vent hole on excess cement expressed at the crown-abutment margin for cement-retained implant crowns. J Prosthodont. 2009 Jan;18(1):54-9.