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The Fracture Resistance of the Posterior Teeth Restored with Different Ceramic onlay Restoration; Systematic review

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Abstract

***Statement of problem**: all-ceramic onlay has become more popular in dental clinics due to their lifelike appearance, durability, and biocompatibility. However, their drawbacks include fracture susceptibility and inadequate marginal fit.*

***Purpose**: The aim of this systematic review was to identify from in vitro studies the fracture resistance of the posterior teeth restored with different ceramic Onlay restoration.*

***Materials and methods**: The articles identified were screened by two reviewers according to inclusion and exclusion criteria. The reference lists of articles advanced to second round screening were hand searched to identify additional potential articles. **Sources**: An electronic search was conducted on PubMed/Medline, Cochrane,google scholar and Lilacs databases with no limitations.*

***Result**: Study selection: 266 articles were identified; ten articles met the inclusion criteria and formed the basis of this systematic review. Factors investigated in the selected articles included the sample size, type of restoration, preparation criteria, method of measuring fracture resistance, and results of fracture resistance.*

***Conclusions**: Adhesive technologies with conservative approach play an important role in development of more preservative & restorative approach even with badly broken down teeth and ceramic Onlay restoration will improve the fracture resistance of the tooth restored ceramic onlay restoration ,the vita enamic hybrid ceramic for partial coverage restorations materials recorded equal fracture resistance when compared with IPS Emax ceramic press.*

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I. Introduction

The concept of bonded all-ceramic inlays and onlays has been introduced to the dental community in the early 1980s [(1)].The increasing demand for esthetics in dentistry has resulted in the development new all-ceramic systems for the fabrication of ceramic inlays and onlays[(2).] Indirect restorations, such as onlays, have become popular, not only due to esthetics, but also because they provide tooth strength and allow for a reduction in the volume of composite resin, which is used only as a luting agent [(3).] Use of adhesive total-cuspal-coverage restorations (overlays instead of crowns) is recommended to reduce the risk of fracture and increase the coronal mechanical resistance [(4).]

Today, with recent advances of resin luting agents, ceramic onlay has become more useful. New types of ceramics with improved esthetic features and durability have been released in the last few years as alternatives to the traditional feldspathic porcelain [(5)].In subsequent years, progress in adhesive bonding techniques and luting composites as well as the ceramic materials with improved mechanical properties lead to a broader range of partial coverage restorations in posterior dentition [(6) .]The primary causes of ceramic inlay or onlay restoration failures are cohesive bulk fractures and marginal deficiencies [(7).] Bulk fracture is still considered one common problem reported in clinical trials. In general, ceramic inlays and onlay are clinically accepted alternatives to cast gold restorations and amalgam fillings. However, failures occur mainly due to fractures, or marginal leakage[(8)].

. Fracture of bonded ceramics becomes a concern when considering the same treatments for posterior teeth. This is particularly the case with restorations covering the entire occlusal surface [(9)]. Investigations of clinically failed all-ceramic restorations have shown that the failure stresses depend on their mechanical properties [(10)].

Before performing in-vivo studies or applying new dental materials for clinical use, in-vitro tests are recommended in order to prove their applicability and performance. In-vitro tests can be performed in a short period of time and have the advantages of reproducibility and the possibility of standardizing the test parameters [(11)].

The physical properties and performance of newly-developed dental materials must be tested before they can be recommended for clinical use [(12)].

Therefore a study performed to investigate the effect of material used for onlay fabrication on the fracture resistance on the molar teeth might be of value since the data in the literature about effect of different ceramic materials on fracture resistance of restored molar teeth has been found to be scarce and rare.

Whether different ceramic materials would affect the fracture strength of the teeth restored with onlay restoration is a question to be answered throughout this study and what type of ceramic restoration should be used for the restoration of large defects in an attempt to prevent fracture and microleakage? And which ceramic materials will perform better in terms of fracture resistance and marginal gap? Hence, the present study was conducted to evaluate and compare the fracture resistance and marginal gap of permanent molar teeth restored with different ceramic Onlay restoration

II. Method And Materials

Data collection: A systematic search of electronic databases was conducted using four databases: PubMed (NLM—National Library of Medicine), Cochrane Library (Wiley) and Lilacs databases up to January 2017. The terms used were Permanent posterior teeth, permanent molars, all ceramic restoration, all ceramic Onlay restoration, dental Onlay, fracture resistance, fracture strength. Specific search strategies for each electronic database are outlined in Table (1). No limits were applied during the electronic searches.

Table 1

Inclusion criteria	Exclusion criteria
✓ Study testing permanent posterior teeth ✓ Articles published in English language ✓ Studies measuring fracture resistance, fracture strength, survival rate ✓ Studies evaluating indirect restoration ✓ Studies measuring fracture strength	☒ Studies evaluating the direct restoration ☒ Studies testing bond strength, color, microleakage ☒ In vivo studies ☒ Teeth with indirect gold onlay restoration ☒ Studies evaluate the full coverage restoration ☒ Non dental study

The initial PubMed search resulted in 210 articles while that of Cochrane resulted in 21 articles and the lilac resulted in 35 while that of ScienceDirect resulted in zero articles while that of SpringerLink resulted in zero articles (total 266 articles). The articles were filtrated by titles/abstracts and resulted in 19 and 13 articles after removal of duplicates. Where a potentially relevant title without a listed abstract was available, the full article was later assessed to select the studies. The total selected articles for full text screening were thirteen articles. According to inclusion and exclusion criteria six articles were excluded and seven articles were included. In addition to three articles obtained from manual searching in references of the included studies.
The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) Statement was used as a reporting template as much as possible and the Search strategy PRISMA flow diagram downloaded as a separate file as shown in table (2).

III. Screening and selection

Initial screening of the titles was conducted to exclude irrelevant articles. Screening the titles and abstracts was performed. The remaining studies were further reviewed by reading their abstracts. If the abstract did not provide enough information to include or exclude a paper, it was selected for full-text reading. Finally, the remaining papers were examined further for their relevance against the inclusion. The Papers that not met the eligibility criteria were excluded from this this study table (3). The Papers that met the eligibility criteria were included in this study and analyzed with regard to the data mentioned in Table (4) criteria by reading them in full text.

IV. Result

Study selection: justified through PRISMA flow chart .Ten studies were included in this systematic review. Among the 21 studies initially considered in the second selection stage, a few studies were eliminated after inclusion and exclusion criteria were applied. In vitro studies that did not analyze the fracture resistance of ceramic materials were excluded. The initial search resulted in 266 articles. Removing the Duplication reduced this number to 264 studies. Then 245 papers were excluded after screening of titles. Abstracts and full texts of the remaining 19 articles were reviewed and led to more exclusion of the non-relevant articles. Six articles were excluded due duplicate removal by to mendeley and in total, 6 papers were excluded after a full-text reading and so the remaining 7 articles were included. In addition three articles were added by manual searching. All data presented in the accepted 10 papers were included in the present study and the data were extracted and summarized in table 5 (summary of findings table).

Table 2: PRISMA flow diagram

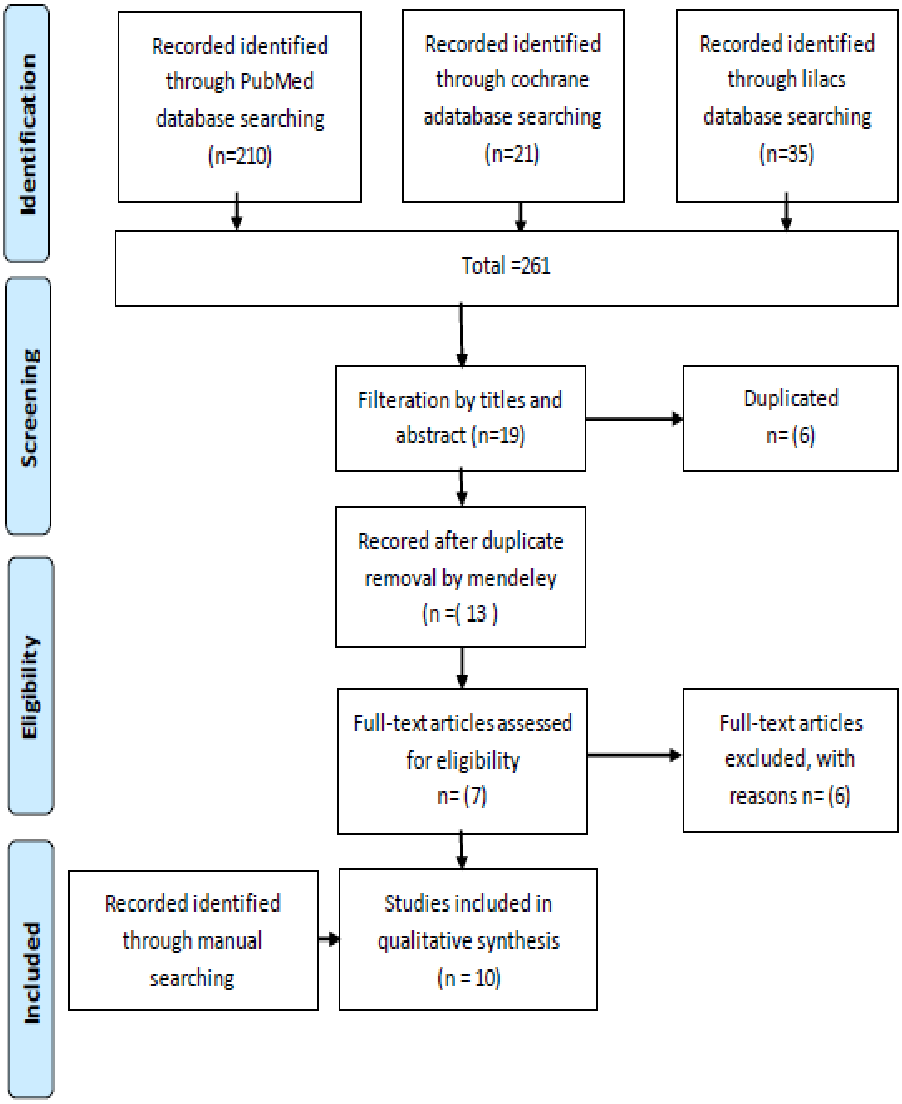

Table 3: List of Excluded articles

No	Titles of articles	Reason for exclusion	Soures
1	Longevity and Clinical Performance of IPS-Empress Ceramic Restorations [13]	A Literature Review	pubmed
2	Clinical efficacy of composite versus ceramic inlays and onlays [14]	systematic review	Pubmed
3	Strength, fracture toughness and microstructure of a selection of all-ceramic materials.Pressable and alumina glass-infiltrated ceramics [15]	Measure the fracture toughness not the F.R	Pubmed
4	Marginal and internal fit of heat pressed versus CAD/CAM fabricated all-ceramic onlays after exposure to thermo-mechanical fatigue [16]	Measure the Marginal and internal fit	lilacs
5	Fracture resistance of endodontically treated premolars restored with lithium disilicate CAD/CAM crowns or onlays and luted with two luting agents [17]	Endodontically treated teeth	pubmed
6	IPS Empress inlays and onlays after four years a clinical study [18]	a clinical study	pubmed

Table 3: List of included articles

NO	Titles of articles
1	Fracture resistance of teeth restored with onlays of three contemporary tooth-colored resin-bonded restorative materials [19]
2	Ceramic inlays: Is the inlay thickness an important factor influencing the fracture risk? [20]
3	Evaluation of Fracture Resistance and Failure Risks of Posterior Partial Coverage Restorations [21]
4	Influence of restorative material and proximal cavity design on the fracture resistance of MOD inlay restoration [22]
5	Risk of onlay fracture during pre-cementation functional occlusal tapping [23]
6	In vitro fatique resistance of CAD/CAM composite resin and ceramic posterior occlusal veneers [24]
7	Influence of ceramic inlays and composite fillings on fracture resistance of premolars in vitro [25]
8	Fracture Resistance of Teeth Restored With All-ceramic Inlays and Onlays: An In Vitro Study [26]
9	Fracture resistance of different partial-coverage ceramic molar restorations An in vitro investigation [27]
10	Effects of different ceramic and composite materials on stress distribution in inlay and onlay cavities: 3-D finite element analysis [28]

Table: 5 Summary of Findings Table (SOFT):

Reference	Study design	Tooth origin (H/B)*	Tooth type Md,M**	No of Gps	No of samples	Inclusion criteria	Exclusion criteria
Brunton et al. 1999) [19]	In vitro	H	Mx-P	4	40	Sound teeth, free of obvious cracks or other imperfections detectable with transillumination	Carious, cracked teeth, or these teeth their occclusal surface obliterated by attrition
Holberg et al. 2013) [20]	In vitro	H	Md-M	2	28	ceramic inlay models with varying thickness (0.7–2.0 mm)	inlay models with thickness more than 2.0mm
Kois et al. 2013) [21]	In vitro	H	Md-M	4	60	**M** selected Immediately following extraction intact, free of cracks or fractures in the crown, caries, and had no prior restoration	**M** were stored for long period, received previous restoration, effected by caries, crack or fracture
Liu et al. 2013) [22]	In vitro	H	Md-M	4	32	**M** with almost the same morphology and without decay and. The maximum width and length of each tooth was within 1 mm	**M** with great variation in morphology, width or more than 1mm, fractured or carious crown
Magne et 2010)[24]	In vitro	H	Mx-M	3	30	freshly extracted, sound **Mx-M** free of cracks or fractures in the crown, caries, and had no prior restoration	**Md-M** teeth with caries, crack or fracture or prior restoration
Magne et al. 2011) [23]	In vitro	H	**Mx-M,P**	3	42	freshly extracted **Mx M** and **P** free of cracks ,attrition and caries	Teeth were stored for long period following the extraction, receiving past restoration
Ragauska et al. 2008) [25]	In vitro	H	**Mx-P**	3	27	Caries-free sound **Mx-P** freshly extracted for orthodontic reasons. buccolingually 9 mm ±10% mesiodistally 7 mm ±10% and with no visible cracks	Dehydrated specimens, narrow attrided, cracked or fractured crown
Relevan 2013) [26]	In vitro	H	Md-M	5	50	freshly extracted, sound, caries and defects free **Md M**, Only intact, noncarious, and unrestored teeth were included in the study	Teeth with great variation in morphology, sever attrition, caries, defect
Strub 2006) [27]	In vitro	H	Mx-M	6	96	caries-free teeth that had been examined visually with a ×10 magnifying glass and had free hypoplastic defects and cracks	teeth stored the teeth longer than three months, teeth with hypoplastic defects and cracks
Yamanel et al. 2009)[28]	In vitro	H	Md-M	4	40	Sound Md-M teeth, free of obvious cracks or other imperfections	Teeth with great variation in morphology, attrition, caries, defect

*H: human, B: boine ** Mx: maxilla, Md: mandible M; molar P; premolar

V. Materials and methods:

Referenc	Cleaning /storage medium	ArtificialPD by	Bone simulat by	Type of Onlay/ inlay materials And grouping	Preparation design	Luting cement	No. of thermo Cycling/pretesting storage in	outcome	Measuring device
Brunton et al. 1999)[19]	stored under water 24h	Gum resin 0.25m	acrylic resin to within 2 mm of CEJ	I. SR Isosit indirect composite II. Belle Glass indirect composite III.Empress ceramic	Gp1=control without preparation. Gp2+Gp3+ G4 =onlay prep	Variolink II	sterile water for minimum period of 24 h	Fracture Resistanc	Universal testing machine 1.5mm/min parallel to long axis of the tooth
Holberg et al. 2013 [20]		The mand included the (PDL) and the first mand molar. All these scanned by CT Using the software Amira.		I -Empress ceramic. II- e.max ceramic	all ceramic inlay(W=2 m A =108)	Variolink II		Fracture risk	Universal testing machine
Kois et l 2013 [21]	0.5% sodium hypochlorite	sticky wax	acrylic resin	I.feldspathc ceramic, II leucite-reinforced ceramic, III.lithium disilicate ceramic VI. indirect composite	2-mm occlusal reduction maintaining cusp steepness of 45 degrees relative to occlusal surface	RelyX slef adhesive cement	In water at room temperat prior to the testing	Failure risk	universal testing machine
Liu et al. 2013) [22]	stored in thymol solution at 4◦C for about one M	-	Orthod resin 2m below the CEJ	I.composite resin block. II-IPS Empress ceramicCAD	two cavity designs, non-proximal box and with proximal box.	RelyX slef adhesive cement	5500 cycles 5-55 ◦C	Fracture resistance	Material Testing System, crosshead speed of 0.1 mm/min.
Magne et al. 2010)[24]	stored in solution saturated with thymol)	-	acrylic resin up to 3 mm below CEJ	I-leucite-ceramics. II-lithium disilicate ceramics. III.composit resin	Standardized prepara-for all specimens. B and P margins at 2.3 to 2.6 mm above the central groove	(Z100; 3M ESPE)	distilled water at temperat for 24 hours before testing	Fatique resistance	closed-loop servo hydraulics (Mini Bionix II; MTS Systems

Reference	Cleaning /storage medium	Artificial PDL by	Bone simulatio by	Type of Onlay/ inlay materials And grouping	Preparation design	Luting cement	No. of thermo cycling/pre testing storage in	outcome	Measuring device
(Magne et al, 2011)[23]	stored in solution saturated with 0.1% thymol	Two layers of water-based liquid latex (Rubber-Sep; Kerr Corporation, Orange, CA)	acrylic resin up to 3.0mm below (CEJ)	I-e.max (lithium disilicate. II-MZ100 (composite resin) III-MK II (feldspathic porcelain)	mesio-occlusal onlay preparation, (two mesial reduced 1.5-mm and covered)	-	-	Fracture risk	An artificial mouth using closed-loop servohydraulics.(Mini Bionix II; MTS Systems, Eden Prairie, MN)
(Ragauska et al, 2008)[25]	Stored , frozen to reduce pulpal cell damage Then in 0.9% sodium-chloride solution changed every 7 days, in a refrigerator at 40C	0. 3 mm low viscosity vinyl polysiloxane (Flextime, Heraus Kulzer GmbH, Germany)	Self-cure acrylic resin 2 mm below cement-enamel junction	I-intact teeth (control group) II-indirect leucite reinforced ceramic III-direct high viscosity hybrid composite	MOD cavities were prepared for groups II and III, total occlusally divergent angle of walls was 10° With a 2 mm deep pulpal floor. buccolingual widths. Each box had a gingival floor depth of 2 mm	(RelyX Adhesive Resin Cement,	-	Fracture resistance	universal testing machine at across head speed of 0.5 mm/ min
(Relevance 2013)[26]	in distilled water until use	0.2-mm layer of a polyether material	Self-cure acrylic resin	I -intact teeth (control) II-inlay with IPS e.max ceramic III- inlays with zirconia ceramic VI.Onlay IPS e.max ceramic V- Onlays with zirconia	The pulpal floor was prepared to a depth of 2.5 mm; occlusal isthmus was 2.5 mm, wide box had a gingival floor depth of 1.5 mm The onlays prepared using basic techniques, the MB and DB cusps were reduced by 2 mm	Variolink II	At 58C -55C for5000 cycles. The time at each temperature was 30 second	Fracture resistance	universal testing machine at a crosshead speed of 0.5 mm/min

Referenc	Cleaning /storage medium	Artificial Periodonal Ligament by	Bone simulation by	Type of Onlay/ inlay materials And grouping	Preparation design	Luting cement	No. of thermoCycling/pretesting storage in	outcome	Measuring device
(Strub 2006)[27]	0.1% thymol solution at room temper	0.25 mm–thick layer of gum resin 2 mm short of CEJ	polymer polyester resin	IPS e.max Press	G1:intact teeth G2-(MOD) inlay preparation G3:Onlay with reduction of the MP cusp G4:Onlay reduction with of both P cusps G5:Onlay with reduction of the both palatal and DP cusps G6:Onlay with covering of all cusps	Variolink II dual-cure resin composit	5,300 thermal cycles	Fracture resistance	Computer-controlled mastication simulator(type N6C41/N6 W26, Willyteh, Munich,specimens demonstrated fracture strength
(Yaman el et al. 2009)[28]	-	-	New mesh structure was constructed for the cortical bone of 1.5 mm thickness .mesh structure of the solid 3D model was created using the to generate solid model	Two nanofilled resin composite 1-Filtek Supreme XT 2-Grandio Two ceramic 1-IPS Empress 2 2- Lava	3-D inlay and onlay cavity designs were created with 2.7 mm cavity depth, 2.3 mm isthmus width, and 1.2 mm gingival wall width. The cavity walls tapered 5°	-	-	stress distribution	Von Mises, compressive, and tensile stress

B=buccal **P**=palatal **MB**=mesiobucall**DB**=distobucal**PDL**=periodontal ligament

VI. Result

NO	Auther and date	result
1	**(Brunton et al,1999) [19]**	Teeth restored with composite onlay restorations demonstrated a higher fracture resistance than equivalent sized onlay restorations produced from fiber-reinforced composite or a ceramic material
2	**(Holberg et al. 2013)[20]**	The inlay thickness does not seem to be an important factor influencing the fracture risk of ceramic inlays. However, further studies are necessary to confirm this.
3	**(Kois et al. 2013)[21]**	Fracture resistance and failure risks of posterior partial coverage restorations are significantly influenced by material selection. All-ceramic materials revealed high incidence of fractures of material itself, whereas the failure of resin-based e involved more to the remaining tooth structure
4	**(Liu et al. 2013)[22]**	For teeth restored with MOD inlays, the use of resin composite as the restorative material may provide higher fracture resis- tance than using ceramic. Using a proximal box design for the cavity may further improve the fracture resistance of the inlay restoration
5	**(Magne et al 2010) [24]**	Posterior patial coverage made of composite resin (Paradigm MZ100) had significantly higher fatigue resistance (P<.002) compared to IPS Empress CAD and IPS e.max CAD.
6	**(Magne et al. 2011)[23]**	Material selection has a significant effect on the risk of CAD/CAM onlay fracture during pre-cementation functional occlusal tapping with composite resin onlays showing the minimum risk compared to ceramic ones.
7	**(Ragauska et al. 2008)[25]**	The ceramic inlays in premolars have higher load to fracture value than composite fillings and similar to intact teeth. Both restorations, ceramic and composite in the premolars, tended to fracture together with palatal cusp of tooth
8	**(Relevance 2013)[26]**	Cuspal coverage decreased the fracture resistance of the posterior tooth and the fracture modes in lithium-disilicate glass- ceramic samples were generally restricted to the restoration itself. Conversely, the fracture modes of zirconia samples generally involved both the restoration and the tooth
9	**(Strub 2006) [27]**	All-ceramic PCRs for molars made of IPS e.max Press were shown to be fracture-resistant, results comparable with those of natural unpre- pared teeth
10	**(Yamanel et al. 2009) [28]**	The all-ceramic inlay and onlay materials tested transferred less stress to the tooth structures. On the effect of cavity design, the onlay design was more efficacious in protecting the tooth structures than the inlay design

VII. Discussion

The present study examined the reliability of posterior all-ceramic partial coverage restoration (PCR) that was created by different materials and corresponding fabrication techniques. The Fracture resistance posterior partial coverage restorations are significantly influenced by material type. All-ceramic restoration show high fractures incidence of material itself, whereas the failure of resin-based restoration involved more to the remaining tooth structure**.** All specimens of ceramic onlay shown fracture resistance that was comparable with those for natural unprepared teeth (fracture resistance mean of unprepared teeth= 2905.3N)(79,135) due to increased crystal in the ceramic, this filler provides a tighter interlocking matrix in its structure and prevents the propagation of microcracks[(29).] Once the crack starts, it will propagate promptly, and no diversion of the crack would occur within the ceramic matrix [(30)]. significant difference in the fracture load of IPS Empress 2 (hot pressed) and ceramic restoration made by CAD/CAM technique (CEREC 3, CAD/CAM) all-ceramic crowns, and conducted that the mechanical properties of ceramic-polymer hybrid materials similar or slightly inferior to lithium disilicate[(31)].

Clinical trials have shown the treatment option to restore posterior teeth with pressed glass ceramics and CAD/CAM fabricated restorations to be reliable [32]**.** Conversely the Modification to the manufactured pressablee.max ingot or the spruing or pressing procedure may also help to produce more uniform crystal dispersion, reducing the susceptibility of the glassy matrix to fracture [33]. On the other hand; machining systems can create a multitude of flaws of a sufficient size to act as fracture sources. These flaws may be related to both material and machining variables, which dramatically improve fracture possibilities this may affect the fracture resistance of the vita enamic ceramic [34]**Coldea et al 2013** [35]suggested that "propagating cracks are deflected and experience a more tortuous path resulting in rough surfaces " This suggests that cracks induced by stress run through the ceramic parts in IPS e.max press ceramic but deflect more at the polymer ceramic interfaces in hybrid ceramic . Also **Stappert et al 2007** [36] reported a significantly higher fracture load for CAD/CAM-produced partial coverage restorations than that of lithium disilicate glass ceramics (and IPS e.max press) fabricated by hot pressing. Many reasons have been given for the failure of all ceramic restorations. The principal problems associated with the ceramic inlay appear to be related to cavity preparation, patient occlusion, cementing agents, insufficient thickness and internal defects of ceramics [37].Some studies have identified a higher incidence of failure of these materials, possibly due to the brittle nature of ceramics, plus a potential abrasive effect on opposing dentition [38]. Long-term clinical data covering observation periods of 17–18 years with feldspathic ceramics and CAD/ CAM systems are reported [39].The survival rate for partial ceramic crowns is similar to the that of partial gold crowns and amalgam restorations [40].

With advancements in material sciences and adhesive technologies, all-ceramic onlay restorations have proven to be fatigue resistant enough to fulfill both functional and aesthetic requirements of the oral environment. With regard to tooth colored inlays and onlays, factors affecting overall restoration longevity may be related to luting and finishing procedures and on the width and performance of the restoration [41].The partial ceramic crowns suffered a fracture rate of 25% after an observation period of 6–84 months [40]. The failure rate of indirect composite inlays and onlays is between 11.8% [42]. Previous studies revealed the high survival rate of ceramic onlay restoration, between 92% and 97% during observation periods of 5 years [43], and 94% to 98% at the seven and eight-year respectively [44]. In contrast other author report that the survival rate of onlays made of feldspathic ceramics was lower with 56–60.7% after an of 6–7 years[45], Other two studies of all-ceramic partial-coverage crowns reported survival rates after 7 years of 81%5 and 56% [44], ceramic fracture was the most frequently reported cause of failure [45].

VIII. Conclusion

Conservation in teeth preparation should be always considered when possible.The material used for fabrication of the indirect ceramic restorations has a crucial effect on its performance regarding the fracture resistance. The materials either the machined or pressed restoration restored the fracture resistance of prepared tooth.Adhesive technologies with conservative approach play an important role in development of more preservative & restorative approach even with badly broken down teeth.

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