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Fixed Zirconia Partial Denture

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ABSTRACT

Background: Ceramics have anextended history in fixed prosthodontics of attaining optimal esthetics. Yttrium tetragonal zirconia polycrystal (Y-TZP)-based systems are a recent addition to the high-strength, all-ceramic systems used for crowns and fixed partial dentures, the highly esthetic nature of zirconia coupled with its superior physical properties and biocompatibility have resulted in restorative systems that meet optimal recent demands.

Aim of the study: systematically review relevant contemporary literature regarding investigating the strength and accuracy of fit of zirconia fixed partial dentures (FPD).

Methods: A systematic review of the scientific literature from 2000 to 2017(PubMed,Embase and CENTRAL Cochrane Central Register of Controlled Trials, CINAHL, Google Scholar as well as individual Dentistry journals such as International Journal of Prosthodontics, International Journal of Periodontics and Restorative Dentistry. We followed PRISMA/STROBE guidelines. Medline abstracts were retrieved using an algorithm comprising relevant MeSH terms.

Results: The search yielded 11 studies enrolling 231 cases that met the inclusion criteria of the review. Absolute, Vertical and Horizontal margin gaps were recorded . Four of them were *in- vivo* studies while seven were *in Vitro*.The study outcome was focused on the assessment of the internal fit as well as the Marginal fit of zirconia FPDs versus the effect of various parameters of CAD ⁄ CAM and CAM systems, post-sintered and pre-sintered milling, framework configuration, veneer application and ageing. Average absolute marginal(AM) gap= 92 microns. For each system, the values were; Everest= 121 , Lava= 71, Cercon = 93.5, Procera = 51, Xawex = 147, CerecInLab = 88.8

Conclusion: It was concluded that CAD/CAM have more accurate marginal and internal fit compared to CAM in fabricating zirconia frameworks. Moreover, post-sintered milling will most likely result in complex geometry and longer span FPDs. Nevertheless, the clinical implications of this difference have yet to be determined, and the pros and cons need to be taken into account first provided the hardship of post sintered milling. Veneering zirconia frameworks resulted in deterioration in fit, ageing of zirconia had no implications on the fit.

Keywords: Zirconia , fixed partial dentures, Flexural strength; Framework design, ceramic restorations.

INTRODUCTION

There is a compelling need from patients worldwide to an aesthetic ideal of the restorations placed in the mouth, which has pushed the scientific research towards the finding of a material that has the necessary mechanical strength suitable to withstand masticatory loads that develop in the posterior areas of the oral cavity in addition to the aesthetic characteristics. Non-metallic restorations have always represented a challenge for dentistry and only in recent years, with the introduction of zirconia, has achieved this objective[1].

High stress-bearing posterior fixed partial dentures (FPDs) were considered a contraindication of all-ceramic materials. Nevertheless, the use of ceramic materials to produce large frameworks and developments in ceramic materials such as zirconium oxide cores, as well as in the field of computer-aided design/computer-assisted manufacture (CAD/CAM)in dentistry has paved the way for high fracture toughness zirconia-based ceramics[2].

Y-TZP (Yttria partially stabilized tetragonal zirconia) frameworks are manufactured with the use of CAD-CAM technology, by milling partially or densely sintered pre-fabricated blocks. Milling densely sintered blocks produced by hot isostatic pressure (HIP) has the advantage of ensuring better adaptation of the final crown. Yet, milling hard structures is quite slow, inefficient and causes excessive wear of the milling burs. Contrariwise, using partially sintered blocks increases the efficiency of the milling process. In such cases, the CAD-CAM system should produce larger restorations to compensate the

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sintering shrinkage, and to ensure adequate fit of the crown [3].

The CAD-CAM technique uses a series of processing steps, such as scanning, software designing, milling and sintering, which may interfere with the precision of fit of the restoration. Although the sintering shrinkage of restorations obtained from partially sintered blocks can be compensated by milling enlarged restorations, it is not as yet clear whether this compensation is effective for the production of FPDs with long spans. Moreover, previous studies reported that the internal adaptation of CAD-CAM restorations is poorer, compared with marginal adaptation [4].

Although the accuracy of fit has a considerable effect on the clinical success of the restoration, there are only a few studies using the new zirconium oxide ceramics and CAD/CAM technology, especially in posterior FPDs[5].

In general, CAD/CAM systems have been used for the fabrication of fixed prosthodontic restorations, such as inlays, onlays, veneers, and crowns. Several commercial CAD/CAM systems that use zirconia-based ceramics include the Lava™ system (3M ESPE, Seefeld, Germany), Kavo Everest® (Kavo, Biberach, Germany), and Cercon® Smart ceramics (DeguDent, Hanau, Germany) [6].

The zirconia blocks provided with these ceramic systems are offered in fully sintered and presintered forms. Compared to pre- sintered zirconia, the fully sintered zirconia has a lower volume fraction of pores, a greater strength, and an improved resistance to hydrothermal aging. In addition, the fully sintered zirconia can be milled to the final desired dimensions because no further heat treatment, which would result in a dimensional change, is required [7].

Regrettably, the high strengths of the dense fully sintered blocks result in long milling times and rapid wear of the machining tools. However, while the pre -sintered blocks are easy to shape, they must be sintered after milling for them to achieve their maximum strength. Therefore, when using pre-sintered blocks, sintering shrinkage needs to be considered before milling. Despite this disadvantage, due to shorter milling time, easier processing, and higher productivity, CAD/CAM systems usually use pre -sintered blocks or blanks at the green stage [8].

The aim of this study was to investigate the marginal fit of fixed partial dentures (Absolute , vertical or/and horizontal) made with different computer-aided design/computer-assisted manufacture systems as well as the internal fit.

MATERIALS AND METHODS

We carried out a systematic review of patients underwent Fixed Zirconia Partial Denture operated from January 2000 to 2017.

Data Sources

Literature searches of from MEDLINE (2000–2017), EMBASE (2000– 2017), Cochrane Central Register of Controlled Trials, CINAHL (2000–2017), Google Scholar, and individual Dentistry journals such as International Journal of Prosthodontics, International Journal of Periodontics and Restorative Dentistry. The search terms were used in combinations and together with the Boolean operators OR and AND. 11 articles matched the stipulated criteria and were included in the current review.

Search terms

Keywords, phrases, and MeSH terms searched included “flexible uretero-scopy,” “zirconia” , “FPD”, “bridge “fixed prosthesis” , “fit”, “ margin’” and “fitting surface” .
Authors independently reviewed titles and abstracts and then downloaded relevant studies. References were reviewed for additional studies.

Study Selection and Criteria

Search results were screened by scanning abstracts for the following:

Inclusion Criteria

1- Articles conducted in English or Arabic language
2- Published in peer-review journals
3- Studies investigating marginal adaptation and internal adaptation
4- A minimum of two frameworks are tested in each sample and a minmum of one of the test specimens was frameworks fabricated by partially stabilised zirconia

Exclusion Criteria

1- Publications conducted in languages other than English and Arabic languages.
2- Articles that didn’t meet the present study endpoint (different intervention technique and target study group).

Data Extraction

Two reviewers independently reviewed studies, abstracted data, and resolved disagreements by consensus. Studies were evaluated for quality. A review protocol was followed throughout.

Study Outcomes

- **Vertical marginal discrepancy (VM):** distance between the restoration and the preparation when measured parallel to the long axis of the abutment.

- **Horizontal marginal discrepancy (HM):** distance measured perpendicular to the long axis of the abutment.
- **Absolute marginal discrepancy (AM):** angular combination of the vertical and HM discrepancies, or the distance between the margin of the casting to the cavosurface angle of the preparation.

The internal adaptation was split into two axial adaptation and occlusal adaptation.

The study was done according to the ethical board of King Abdulaziz university.

RESULTS

Electronic Searches identified 174 publications in addition to another 21 publications that were found through manual research. After removal of duplicates, abstracts and titles 113 publications were assessed as identified from title and abstract and 54 papers were excluded. 8 papers full text could not be retrieved and another 14 papers with the same cohort. There were also 26 papers excluded because they did not meet the endpoint; the study outcome. We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[9]in reporting the results. **Figure 1**

Data extracted using a standard protocol concerning target population, sample size, intervention components, processes, and outcomes. Comparison among provider type was computation of differences between percent of successful program to number attempted. No further statistical analyses were employed.

Finally,11 studies [10-20]were included and detailed as the focus for the present study.

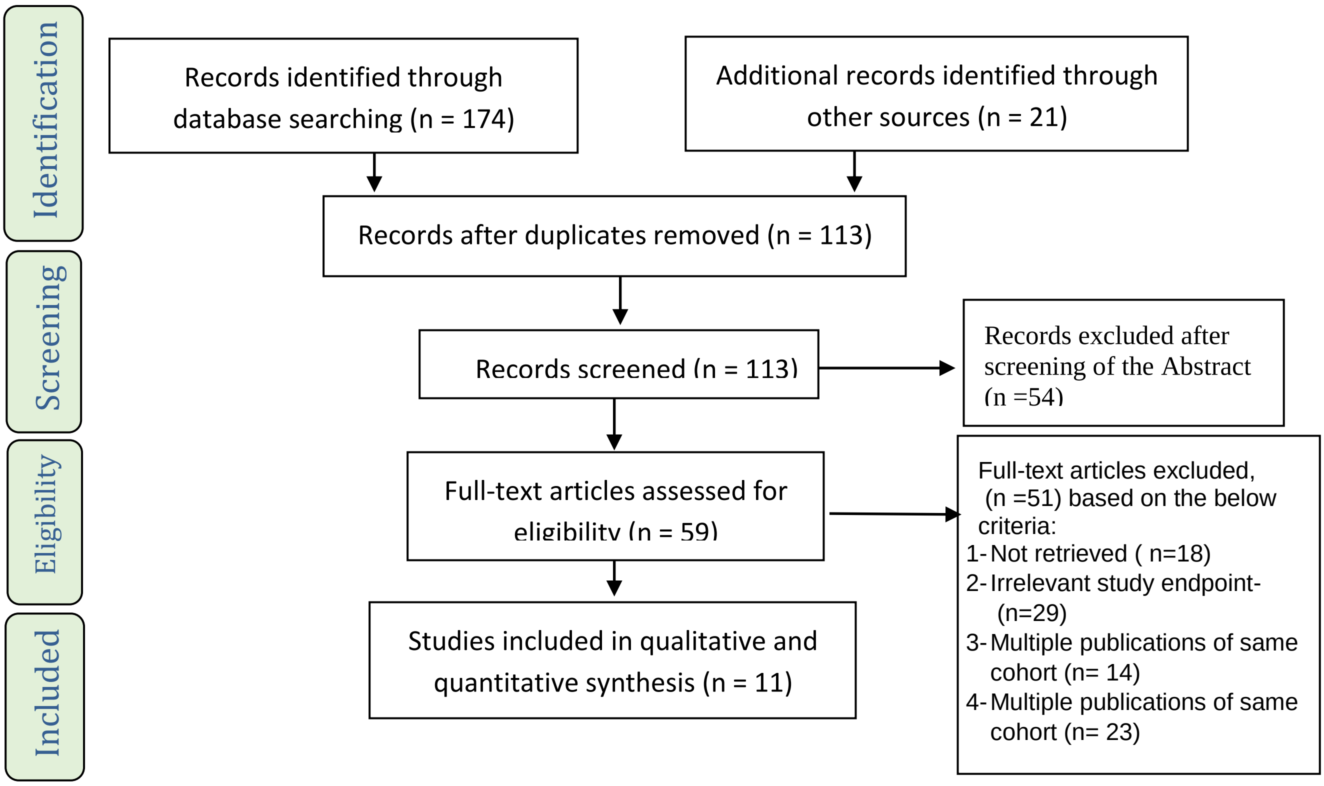

Figure 1: PRISMA flow diagram showing the selection criteria of assessed studies[22].

Table 1: baseline characteristics of the included study

Authors	Year of Publication	Sample size	Prostheses state	State	Span	Manufacturer
***Kohorst et al.* [10]**	2010	10	Framework	Pre-sintered	4	Everest
			Veneered			CAD/CAM
		10	Framework	Pre-sintered	4	CerecInLab
						CAD/CAM
***Att et al.* [11]**	2009	8	Framework	Post-sintered	3	DCS
			Veneered			CAD/CAM
			Cemented			
			After ageing			
		8	Framework	Pre-sintered		Procera
			Veneered			CAD/CAM
			Cemented			
			After ageing			
		8	Framework	Pre-sintered		CerecInLab
			Veneered			CAD/CAM
			Cemented			
			After ageing			
***Dittmer et al.* [12]**	2009	10	Framework	Pre-sintered	4	Everest
			Veneered			CAD/CAM
***Gonzalo et al.* [13]**	2009	10	Veneered	Pre-sintered	3	Procera
			Cemented			CAD/CAM
		10	Veneered	Pre-sintered	3	Lava
			Cemented			CAD/CAM
***Kohorst et al.* [14]**	2009	10	Framework	Pre-sintered	4	CerecInLab
						CAD/CAM
		10		Pre-sintered	4	Everest
						CAD/CAM
		10		Pre-sintered	4	Cercon
						CAM
		10		Post-sintered	4	Digident
						CAD/CAM
***Reich et al.* [15]**	2008	24	Veneered	Pre-sintered	4	Lava
						CAD/CAM
***Wettstein et al.* [16]**	2008	16	Veneered	Pre-sintered	3	Cercon
						CAM
***Bindl and Mormann* [17]**	2007	2	Framework	Pre-sintered	3	CerecInLab
						CAD/CAM
		2		Post-sintered	3	DCS
						CAD/CAM
		2		Pre-sintered	3	Cercon
						CAM
***Tinschert et al.* [18]**	2005	5	Framework	Post-sintered	3	DCS
		5			4	CAD/CAM
		5			5	
***Komine et al.* [19]**	2005	8	Straight	Pre-sintered	4	Cercon
			Framework			CAM
		8	Curved		4	
			Framework			
		8	Straight	Pre-sintered	4	CerecInLab
			Framework			CAD/CAM
		8	Curved		4	
			Framework			
		8	Straight	Pre-sintered	4	Xawex
			Framework			CAD/CAM
		8	Curved		4	
			Framework			
***Reich et al.* [20]**	2005	8	Veneered	Pre-sintered	3	Lava
						CAD/CAM

The included articles characteristics were heterogeneous regarding sample size, span length, experimental methodology, milling system, manufacturing company and state of the zirconia,
The approaches used for the marginal and internal assessment were:

- External replica approach,
- Internal replica approach,
- External microscopic examination of the marginal area before or after cementation
- Internal microscopic examination after cementation and sectioning of the specimen.

The manufacturing companies for zirconia reported in the included studies were Cercon (CAM), Procera, Lava, CerecInLab, Xawex, Etkon, Everest, Precident DCS (post-sintered milled zirconia), Digident(post-sintered milled zirconia). All were CAD/CAM except Cercon, which was CAM. Digident and DCS systems milled zirconia in the post-sintered state while all the others were in the pre-sintered state.
From the selected studies, five factors were identified to have an influence on the fit of zirconia FPD:

- 1 Differences in fabrication systems (CAD/CAM vs CAM)
- 3 Effect of veneering.
- 4 Effect of framework configuration.
- 5 Effect of zirconia ageing.

The search yielded 11 studies enrolling 231 cases that met the inclusion criteria of the review. Absolute, Vertical and Horizontal margin gaps were recorded . Four of them were *in vivo* studies while seven were *in Vitro*. The study outcome was focused on the assessment of the internal fit as well as the Marginal fit of zirconia FPDs versus the effect of various parameters of CAD ⁄ CAM and CAM systems, post-sintered and pre-sintered milling, framework configuration, veneer application and ageing.Average absolute marginal (AM) gap= 92 microns. For each system, the values were; Everest= 121 , Lava= 71, Cercon = 93.5, Procera = 51, Xawex = 147, CerecInLab = 88.8. The detailed outcomes per study are shown in table 2.

Table 2: Summary of the marginal and internal fir outcomes of the included studies
NA, not available; GIC, glass ionomer cement; CAM, computer-aided milling; CAD/CAM, computer-aided design and computer-aided manufacturing

Authors	Manufacturer	Fit				Examination method	
		Marginal (µm)			Internal (µm)		
		Absolute	Vertical	Horizontal	Axial	Occlusal	
***Kohorst et al.* [10]**	Everest	129.3	NA		NA	112·3	*In vitro*
	CAD/CAM	112.8			NA	95·8	Internal replica approach (×51·2)
	CerecInLab	102.3			NA	81·0	
***Att et al.* [11]**	CAD/CAM	86	NA		NA	*In vitro*	
	DCS	86				Cemented with GIC	
	CAD/CAM	86				External replica approach (×250)	
		84					
		82					
	Procera	89					
	CAD/CAM	89					
		88					
		64					
	CerecInLab	67					
	CAD/CAM	76					
		78					
***Dittmer et al.* [12]**		129.8		37·6	112·3		*In vitro*
	Everest	112.8		26·9	95·7		Internal replica approach (×51·2)
***Gonzalo et al.* [13]**	CAD/CAM	9	NA		NA	*In vitro*	
	Procera	12				Cemented with GIC	
	CAD/CAM	66				External microscopic examination	
	Lava	71				(×40) magnification	
***Kohorst et al.* [14]**	CAD/CAM	182	111·5	85·8	NA	Internal replica approach (×51·2)	

Authors	Manufacturer	Fit					Examination method
		Marginal (µm)			Internal (µm)		
		Absolute	Vertical	Horizontal	Axial	Occlusal	
	CAD/CAM	206	197·3	37·6			
	CAD/CAM	189	114·5	116·3			
	CAM	60	23·8	51·1			
Reich et al. **[15]**	CAD/CAM	91	NA		98·0	202·0	*In vivo* Internal replica approach (×50)
Wettstein et al. [16]	CAD/CAM Cercon	NA			140·5	192·0	*In vivo* Internal replica approach (×20)
Bindl and Mormann[17]	CAM	53	NA	NA	103·0		*In vitro* Cemented with composite resin cement
	CAD/CAM	32	NA	NA	144·0		Internal microscopic examination after sectioning (×120)
	DCS	120	NA	NA	126·0		
Tinschert et al. [18]	Cercon	67	44·1	56·1	NA		*In vitro*
	CAM	71	46·3	58·8			Internal replica approach (×200)
	DCS	61	46·3	44·8			
Komine et al. [19]	CAD/CAM	80	NA		NA		*In vitro* External replica approach (×40)
	Cercon	120					
		87					
	CerecInLab	97					
		113					
	Xawex	147					
Reich et al. [20]	Lava CAD/CAM	80	NA NA	NA NA	132·0	215·0	*In vivo* Internal replica approach (×50)

DISCUSSION

In the present study, our objective was to investigate the different systems for zirconia framework fabrication that has influence on the final marginal and internal fit.

There was a significant variation between the values obtained by the different studies and such variation existed even for the same system which could be related to the study design and measurement procedure. Having such heterogeneity hindered the ability to exactly propose the optimal and most accurate system.

Hence, in the following we had explored the different factors and systems which could induce an effect on the fit of zirconia fixed partial denture.

Comparison between CAM and CAD / CAM

The CAD/CAM process was capable of three types of production:

a) **Laboratory production:** where an impression was sent to the laboratory and all the CAD/CAM equipment for design and fabrication of the prosthesis were located at the laboratory. The scan of master cast, 3D design of the prosthesis and milling the products takes place remotely.
b) **Chairside production**: where all of the system components were available at the dental office.
c) **Centralized production**: where the scanner and software was located at the dental office. Data sets were typically referred to the laboratory for CAD/CAM fabrication of the product.

As for CAM system, Wettstein et al. [16] found that CAM zirconia frameworks exhibited a larger internal gap than gold alloy frameworks. In this study, the wax patterns for the zirconia and gold alloy frameworks were constructed by one experienced dental technician.

Building on this remark , Bindl and Mormann[17] showed that CAD ⁄CAM provided significantly better marginal fit compared to CAM systems. It could be concluded that scanning the wax pattern by CAM system is much less accurate than a wax pattern and casting with a precious metal. Moreover, conventional casting technique proved to be more accurate than zirconia fabrication, precisely if produced by CAM.

In brief,unlike CAM system, CAD ⁄CAM might be a competitive alternative to the conventional casting.

- ***Miling effect on Zirconia***

The zirconia blocks were divided into fully sintered and pre -sintered forms. Compared to pre -sintered zirconia, the fully sintered zirconia has a lower volume fraction of pores, a greater strength, and an improved resistance to hydrothermal aging. In addition, the fully sintered zirconia can be milled to the final desired dimensions because no further heat treatment, which would result in a dimensional change, is required[21]. Though the high strengths of the dense fully sintered blocks bring about rapid wear as well as long milling times and of the machining tools. On the other hand, although the presintered blocks were easy to shape, they must be sintered after milling in order for them to achieve their maximum strength. Therefore, when using presintered blocks, sintering shrinkage needs to be considered before milling. Despite this disadvantage, due to shorter milling time, easier processing, and higher productivity, CAD/CAM systems usually use presintered blocks or blanks at the green stage.

In relation to our study , Kohorst et al. [10] found milling post-sintered zirconia provided a superior vertical, horizontal and AM fit than pre-sintered milling. In contrast, Att et al. [11] showed that milling at the pre-sintered stage provided a superior outcome compared with post-sintered milling. Only one study assessed the internal adaptation of pre and post-sintered milling of zirconia and did not show an advantage of milling zirconia at the post-sintered stage.

Effect of configuration

Calha et al.[22]suggested that the geometric configuration influences the deformation of 4-unit anterior frameworks under static load. The higher strain distribution and micro-movements of the curved frameworks reflect less rigidity and increased risk of fractures associated to FPDs.Komine et al. observed a noticeable effect of shrinkage of partially sintered zirconia during sintering that affects the resultant dimension of the FPD frameworks. They assumed that more complex configurations might affect the pattern of distortion because of shrinkage. In the light of their results, hard machining might result in a more predictable margin with complex designs, as it will avoid the risk of sintering shrinkage[19].

Effect of veneering

Metal or zirconia core materials must be covered with a feldspathic veneering ceramics to establish an optimum esthetic outcome especially color and translucency[23]. Different techniques, including layering and pressing techniques, can be performed for veneering ceramic on core materials. In the layering technique, the porcelain powder is mixed with modeling liquid, and the mixture is brush-applied on the core (metal or fully-sintered zirconia) larger than the final dimensions to compensate for the shrinkage of the veneering ceramic[23].

in the pressing technique, prior to investing, a final contour anatomical waxing is prepared on a core. After elimination of the wax in an oven, ceramics are heat-pressed into the mold and to the core[23]. This technique has some advantages on the layering technique with its speed, accuracy and stability. Ceramic structures tend to fail because of surface tension, where cracks and flaws propagate by slow crack growth leading to the failure. The flaw size, number and distribution can be related to the material, or be affected by the fabrication process. Chipping can be attributed to potential flaws and artifacts generated during the veneering technique. As the pressing technique is a more controlled procedure, fewer flaws and better strength properties are expected than the layering technique[24].The shrinkage level of the porcelain may be related to the ratio of the mixed powder/liquid veneering ceramic and minimal three firing cycles are required. Catastrophic failures may also be induced by the incorporation of small impurities like pores, since cracks cannot be healed, but slow growth may occur under oral conditions.

Kawai *et al*.[25]concluded that more plaque was adhered over glazed surfaces of ceramics as compared with their polished surfaces. This means that a glazed surface would not be clinically acceptable from a biologic point of view. Glazing can produce an undulating and rough surface that, usually, has irregularities, inducing more adhesion of bacteria and other substances.

Att et al. [11] found an increase in marginal discrepancy because of veneering the zirconia framework, however, that effect was minimal. On the contrary, Dittmer et al. (12) , and Kohorst et al. [10]found that veneering has the tendency to decrease the AM gap, internal gap and horizontal discrepancy. From their observation, it was found that the distortion was directed towards the center of the retainers. The differences between the various studies could be related to margin design, porcelain firing cycles and relative thickness of the veneering ceramic and zirconia framework.

From the available studies, it seems there is a potential for the veneering process to influence the fit of the restoration. However, the degree of this distortion is not yet quantified.

Effect of zirconia ageing

Thickness of zirconia has significant effect on translucency. Aging has significant effect on thinner sections of zirconia. More research studies are required on zirconia metal towards making the material more translucent due to its potential use as esthetic monolithic restoration. Aging related changes in the microstructure that leads to changes in the mechanical properties would also lead to optical changes. Nevertheless, through studying of the factors controlling LTD and their effects on the material microstructure and surface, esthetic outcome and stability of the material with its variable products and processing techniques may to a great extent be affected[26].

Att et al. [11]found that masticatory and thermal stimulation has an insignificant effect on the marginal fit or zirconia FPDs. Such findings indicate the long-term stability of zirconia restoration margin.

CONCLUSION

Most of the available systems to fabricate zirconia frameworks have the tendency to provide clinically adequate marginal adaptation and internal space. However, there is considerable variation between the results obtained by the different systems. Such variations indicate a need for further refinement and improvement of the scanning, designing and milling apparatus.

2 Computer-aided design and computer-aided manufacturing showed more accurate marginal and internal fit compared to CAM in fabricating zirconia frameworks. Post-sintered milling is more predictable for more complex geometry and/or longer span FPDs. The clinical implications of this difference have yet to be determined, and the advantages in accuracy should be weighed against the difficulties of post-sintered milling.

3 Several studies showed a negative effect of veneering ceramic on the marginal fit of zirconia frameworks. The parameters that might increase the effect of distortion have yet to be determined. They could include firing cycles, framework dimensions and margin design. Ageing has not proved to cause marginal deterioration of zirconia prosthesis.

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