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A review on the prevalence of marginal discrepancy between lithium disilicate and zirconia crowns manufactured using dental cad cam

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ABSTRACT

Dental CAD/CAM technology is gaining popularity because of its benefits in terms of manufacturing time, material savings, standardization of the fabrication process, and predictability of the restorations. When the CAD/CAM manufacturing process is employed, the number of steps required for the fabrication of restoration is less compared to traditional methods. One more benefit of CAD/CAM dentistry includes the use of materials and data acquisition instruments, that shows a non-destructive method of saving impressions, restorations and information that are saved on a computer and constitute an extraordinary communication tool for evaluation.



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INTRODUCTION

Dental crowns have been used for decades to restore compromised, carious and endodontic treated dentition for function and esthetic improvements. New CAD/CAM materials and systems have been developed and evolved in the last decade for fabrication of zirconia and lithium di silicate restorations.

Dental CAD/CAM technology is gaining popularity because of its benefits in terms of manufacturing time, material savings, standardization of the fabrication process, and predictability of the restorations. When the CAD/CAM manufacturing process is employed, the number of steps required for the fabrication of restoration is less compared to traditional methods. One more benefit of

CAD/CAM dentistry includes the use of materials and data acquisition instruments, that shows a non-destructive method of saving impressions, restorations and information that are saved on a computer and constitute an extraordinary communication tool for evaluation. Cooper (2011) stated that: "CAD/CAM technology is an efficient and effective point for the critical evaluation of the proposed restorations prior to its fabrication" (Cooper AL 2011).

The incorporation of dental technology has not only brought a new range of manufacturing methods and material options but also some concerns about the processes involving restorations fit, quality, accuracy, short and long-term prognosis (Miyazaki T, *et al.*, 2009). The purpose of this review is to provide an overview of the literature regarding the difference in the marginal fit of zirconia and lithium disilicate crowns manufactured by CAD CAM technology.

Lithium disilicate

Lithium disilicate is composed of quartz, lithium dioxide, phosphor oxide, alumina, potassium oxide and other components. According to Saint-Jean (2014), the crystallisation of lithium disilicate is heterogeneous and can be achieved through a two or three stage process depending if the glass-

ceramic is intended to be used as a mill block (E-max CAD) or as a press ingot (E-max press).

Lithium disilicate blocks are partially sintered and relatively soft; they are easier to mill and form to the desired restoration compared to fully sintered blocks; after this process, the material is usually heated to 850°C for 20-30 minutes to precipitate the final phase. This sintering step is usually associated with a 0.2% shrinkage accounted for by the designing software (Shen JZ, Kosmač T. 2013).

Nowadays, blocks of lithium disilicate with the commercial name E-Max (Ivoclar Vivadent, Liechtenstein) are available for both in-office and in-laboratory fabrication of all-ceramic restorations; monolithic blocks require layering or staining to achieve good esthetic results (Kelly JR 2004).

IPS e.max CAD is a Lithium disilicate available as a glass-ceramic block (for use in CAD-CAM) used in the fabrication of substructures or full contour restorations. There is a two-stage crystallisation process for IPS e.max CAD blocks/restorations. In the first stage, Lithium metasilicate crystals are precipitated leading to a glass-ceramic material with a crystal size range of 0.2- 1.0 micrometres and about 40 per cent Lithium disilicate crystals by volume. (Fasbinder DJ *et al.*, 2010).

The block in this stage has a characteristic blue-violet colour and is easily milled; reducing wear on the milling burs and preventing damage to the material during machining. After the restoration has been milled in stage one, it is fired at 850°C in a vacuum during stage two. The metasilicate crystal phase dissolves completely to the resulting lithium disilicate glass ceramic structure with a fine-grained size of about 1.5 micrometres and about 70% crystal volume incorporated in a glass matrix. When fired, the material will take on the selected tooth shade. The resulting flexural strength of the material is 360-400 MPa. In a study by Fasbinder, *et al.* (2010) showed that single crowns fabricated with IPS e.max CAD performed well after two years of clinical service.

Different *in vitro* studies that evaluate marginal accuracy of milled lithium disilicate revealed that these restorations could be as accurate as 56-63 microns. (May KB *et al.*, 1998)

In the literature, the clinically acceptable size of the marginal gap varies. Some studies have found <120µm acceptable, while others found anywhere from 50-100 µm to be acceptable (Addi, S 2002; Bindl, A., Mormann, W.H., 2005). One study that compared laboratory processed pressed ceramic onlays to chairside CAD/CAM onlays found that both systems exhibited a clinically acceptable gap width of less than 100 µm (Reich, S., *et al.*, 2008].

Clinical studies are also of interest, and one such study found that CAD/CAM chairside produced lithium disilicate crowns performed well after two years of clinical service (Piconi C, Maccauro G. 1999).

Zirconia

Zirconia has been used in dentistry as a biomaterial for the fabrication of crowns and FPD's restoration since 2004; it has been especially useful in the most posterior areas of the mouth where high occlusal forces are applied, and there is limited inter-occlusal space (Reich, S., *et al.*, 2008). Dental restorations are made as full contour monolithic structures of frameworks that can be overlaid with porcelain after a cutback for more esthetic results.

Zirconia is a polymorphic material that can have three different phases depending on the temperature: monoclinic at room temperature, tetragonal above 1170°C, and cubic beyond 2370°C. According to Piconi "the phase transitions are reversible and free crystals are associated with volume expansion" (Piconi C, Maccauro G. 1999). Different authors state that when zirconia is heated to a temperature between 1470°C and 2010°C and cooled a volume shrinkage of 25 to 35% can occur that could affect marginal fit or passiveness of the restorations. This feature limited the use of pure zirconia until 1970 when Rieth and Gupta developed the yttria-tetragonal zirconia polycrystal (Y-TZP) containing 2-3% mol-yttria in the intent to minimize this effect (Luthardt RG *et al.*, 1999).

One of the most interesting properties of zirconia is transformation toughening; Kelly (2008) describes it as: "A phenomenon that happens when a fracture takes place by the extension of an already existing defect in the material structure, with the tetragonal grain size and stabilizer, the stress concentration at the tip of the crack constitutes an energy source able to trigger the transformation of tetragonal lattice into the monoclinic phase." This process dissipates part of the elastic energy that promotes the progression of cracks in the restoration; there is a localised expansion of around 3.5% that increases the energy that opposes the crack propagation (Kosmac T, *et al.*, 1999).

One of the first systems that used zirconia was In-Ceram Zirconia (VITA, Bad Säckingen, Germany), which is a modification of the In-Ceram Alumina but with the addition of partially stabilised zirconia oxide to the composition (Sundh A, *et al.*, 2005).

Recently many companies have integrated zirconia into their CAD/CAM workflow due to its

mechanical properties, which are attractive for restorative dentistry; some of these properties are: high mechanical strength, fracture toughness, radiopacity for marginal integrity evaluation, and relatively high esthetics (Raigrodski AJ, 2004).

Different systems in the market are using zirconia as one of their main materials such as: Ceramill Zolid (Amann Girbach, Herrschaft Swiesen, Austria), Prettau (Zirkonzahn, An der Ahr, Italy), Cercon (Dentsply, NY), BruxZir (Glidewell Laboratories, Newport Beach, CA), IPS ZirCAD (Ivoclar Vivadent, Liechtenstein), Zenostar (Ivoclar Vivadent, Liechtenstein), in Coris ZI (Sirona Dental, Charlotte, NC), VITA In-Ceram YZ (VITA, Bad Säckingen, Germany), among others. Companies have introduced materials that are in combination with zirconia to improve its properties in different clinical situations. Lava Plus (3M ESPE, Center St. Paul, MN) for example is a combination of Zirconia and a nano-ceramic. Table 2 describes some of the CAD/CAM materials used by dental clinicians and laboratories for all-ceramic restorations and its restorative indications by the manufacturers. Regarding ceramic restorations, the marginal and internal fits are two of the most important criteria for long-term success, in addition to fracture resistance and aesthetics. A significant space between the tooth and the restoration exposes the luting material to the oral environment, resulting in a more aggressive rate of cement dissolution caused by oral fluids and chemo mechanical forces (Mormann. W.H., 2006). The consequent micro-leakage may result in inflammation of the periodontal tissues, secondary caries, and subsequent failure of the prosthesis (Syrek A *et al.*, 2010). McLean and von Fraunhofer (J.W. McLean *et al.*, 1971) concluded that 120µm was the maximum tolerable marginal opening (U.C. Belser 1985); however, there is no consensus on what constitutes a clinically acceptable maximum marginal gap width. The values reported in the literature have a wide range (50–200 µm) (G.J. Christensen 1966). Moreover, there is no standardisation in the methodology used, which makes data comparison difficult (J.R. Holmes *et al.*, 1989) Marginal gaps of 1–161 µm have been reported in the literature for conventionally fabricated ceramic crowns (P. Schaerer, *et al.*, 1988). In contrast, marginal gaps of 17–118 µm have been reported for CAD/CAM-fabricated ceramic crowns (Sulaiman F *et al.*, 1997). Larger internal discrepancies may have weakening effects on the ceramic. Even for zirconia core materials, an influence of the cement thickness on radial crack growth has been demonstrated (M.J. Suárez, *et al.*, 2003).

A recent clinical study analysed the marginal fit of 20 zirconia crowns from digital intraoral impressions with active wave front sampling and reported a median marginal gap of 49 µm, whilst the control crowns fabricated from conventional impression followed by the same CAD–CAM technology obtained a median value of 71 µm (A. Syrek, *et al.*, 2010). The value of the test group can be considered comparable to the mean value obtained in the present investigation.

Marginal fit

Marginal fit evaluation is considered an essential factor for clinical success. Christensen (1966) reported that clinically detectable subgingival margins are in a range of 34-119 microns and 2- 51 microns for supragingival margins. McLean (1971) suggested that 120 microns should be the limit for clinically acceptable marginal discrepancies.

Poor marginal adaptation can result in dissolution of cement; increase plaque accumulation, periodontal inflammation, and secondary caries. Binl, et al. (2005) did a research study measuring the marginal fit of restorations and defined absolute marginal discrepancy for the first time. This concept states the marginal fit should be considered as the angular combination of the vertical and horizontal error.

Some of the main concerns from clinicians about all-ceramic CAD/CAM restorations accuracy of fit are: scanning resolution, software designing limitations, and milling hardware limitations of accuracy. Clinicians' and technicians' experience with the CAM/CAM system integration is also a key factor for fabricating good restoration; the computer software per se will not allow an inexperienced operator to create an excellent dental restoration from scratch (Martin N, Jedynakiewicz NM 2000).

The clinical evaluation is an evaluation method used to evaluate the marginal fit of restorations especially in clinical in vivo studies; this process is done routinely at delivery and is usually evaluated by the use of instruments like sharp dental explorers. In an article by Hickel (2007) different recommendations regard in the clinical evaluation of restorations were proposed. The use of explorers with blunt tips of 150 and 250 microns is recommended as the development of secondary caries has only been correlated to gaps >250 microns. It has been stated in different studies evaluating restorations made with conventional or digital impressions that marginal gaps that are not clinically detectable represent a harmonious continuation of the junction tooth/restoration. According to Hickel (2007) "gaps that deviate from ideal but could be adjusted

to ideal by polishing are between 50 and 150 microns; gaps with leakage and is colouration on limited to the borders of the restorations are easily perceptible with explorers and are not considered to have a long-term negative impact if they are between 150 and 250; gaps larger than 250 microns should be replaced to prevent secondary caries or large fractures at the margins".

Although in clinical practice the previous methods in addition to radiographs are used to determine marginal fit; several authors have reported the use of other methods to investigate to testing parameters to evaluate the fit of CAD/CAM restorations thesis techniques vary in terms of accuracy, reliability and process of evaluation.

Direct view has been widely used in different studies; this method involves the evaluation of the gap between the crown and the die or tooth; but some of the disadvantages of this techniques is the difficulty of selection for the points that have to be measured and is very difficult to evaluate discrepancies because it is harder to differentiate between the tooth and the cement.

Scanning Electronic Microscopy (SEM) imaging and light microscopy have been used to evaluate the marginal gap of different restorations. Grotnet *et al.* compared the fit to all-ceramic restorations using SEM and light microscopy and found no significant differences between the accuracy of the two techniques, although SEM provided more realistic observations in complex morphologies (Groten *et al.*, 1978). Some authors have reported that other microscopes have been used such as digital microscopy and stereomicroscopy, but these ones show more standard deviation and some of the results are questionable (Nawafleh, N *et al.*, 2013).

The replica technique is done using light body silicone material as a cement substitute during the procedure and then the layer is carefully removed from the die; a heavy body material of a different colour is used to hold the thin layer of the light body. The material replica is sectioned and measured using a microscope. This technique has been widely used but it has been stated that its limitations involve possible alterations and distortions during the impression, difficulty on finding the margins and altered sectioning that could lead to distortions of the measurements. Different authors have performed a variation of the technique; for example Felton *et al.* used a replica of impressions of the margins using low viscosity vinyl polysiloxane materials and then poured a model that can be used for observation with scanning electron microscope (Felton, D *et al.*, 1991).

The cross-sectioning technique allows the direct measurements of the cement thickness and marginal gap, but is dependent on the plane of sectioning of the specimen which at the same time could lead to distortions and also the measurements are limited to the portion of the sample that was sectioned which may or may not represent the complete fit of the crown; it also doesn't allow for long-term analysis and comparison of the results before and after different experimental stages using the same specimens (Sharer, B *et al.*, 1996).

The profilometry is a non-destructive technique, which allows for accurate focus, the sample can be analysed in a focal plane; in case of sequential analysis, extreme care should be taken in repositioning the specimens or problems with re-measuring could occur.

On the other hand, 3D reconstruction uses a scanner with high accuracy that reconstructs the restoration, die and die spacer. This data can be analysed separately using different software and measurements can be done in a circumferential manner. A similar technique can be done using a micro-CT in which a micro-CT scanner is used to scan the specimen and different software's can be used to evaluate the data; the specimens can be evaluated in a circumferential way and a 3D reconstruction of the data can be performed; more precise measurements of the samples can be done by analyzing different points on the different two-dimensional images provided by the data according to the plane in which the data is analyzed. The disadvantages of these techniques involve the technical difficulties of using multiple software's for the analysis of the data.

A literature review about the accuracy and reliability of methods to measure marginal adaptation of crowns and fixed partial dentures by Nawafth, *et al.* (2013) showed that from 183 papers that met the inclusion criteria 47.5% used direct view techniques which was the most commonly used method; it was followed by 23.5% of cross-sectional technique and 20.2% of impression replica techniques; the marginal gap values reported from this methods varied among individual systems, sample sizes and measurements per specimens. CAD/CA techniques also offer the benefit of intraoral data acquisition with "optical impressions" which can help reduce errors associated with conventional impression techniques.

CONCLUSION

Newer all ceramic materials have contributed markedly to fulfil the esthetic, biological and mechanical considerations of CAD/CAM fabricated

restorations. The marginal fit is of great clinical importance for longevity and function of the restoration. This review concluded that the marginal fit of the restorations fabricated using lithium disilicate and zirconia were clinically acceptable. However, there is a need to improve the qualities of these materials to further improve the marginal fit.

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