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Marginal and Internal Fit of CAD CAM System

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Abstract

The marginal and internal fit are the critical factors for a successful prosthesis. So, the aim of this article is to cover all the aspects regarding the measurement methods for the marginal and internal gap and the effect of each stage of CAD/CAM system on the marginal and internal adaption

Keywords: CAD/CAM with Marginal, Internal, Precision, Fit, Adaptation, Discrepancy, Accuracy, Gap, Impressions, Intra-Oral Scanner, Extra-Oral Scanner, Subtractive, Additive, Measurement, Materials

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Introduction

Over the last 30 years, computer-aided design and manufacturing (CAD/CAM) techniques have developed and improved and have led to going beyond the use of traditional techniques. Dental reconstruction with fixed prostheses needs to achieve Precision marginal and internal fit. In CAD/CAM systems each step from scanning to machining, affect the adaptation fit of CAD/CAM systems.

Good marginal fit is the critical factor for the long-term success of fixed prosthesis. poor marginal fit exposes the luting material to the oral environment, thus leading to cement dissolution and induces microbacteria deposits on the plaque, which initiates decay can cause inflammation of the vital pulp and periodontal disease and leads to failure of the restoration[1]. The internal fit should be uniform to avoid compromising either the retention or the resistance also should provide an appropriate luting space.[2] Marginal gap defines as the distance from the margin of a casting to cavosurface angle of tooth preparation. And internal gap it's the perpendicular measurement from the internal surface of the casting to the axial wall of the preparation.[3]

Materials and methods

An electronic search of MEDLINE (PubMed) was conducted an English article. The following keywords were combined 'CAD/CAM' with 'Marginal', 'Internal', 'Precision', 'Fit', 'Adaptation', 'Discrepancy', 'Accuracy', 'Gap', 'impressions.', 'intra-oral scanner,', 'extra-oral scanner', 'subtractive', 'additive'.

Measurements Methods Of Marginal Gap And Internal Fit:

Replica technique (internal replica approach): It is a non-destructive and most commonly used technique. by injecting a light body silicone material in the fitting surface of the crown. After setting of the martial it's can be sectioned and measured at different sites. It has several disadvantages such as limited number of 2D sections and it lacks accuracy because of silicone material peeling off the internal surface of the crown. [4,5]

Cross sectional technique after cementation and embedding (internal microscopic approach): The cross-sectioning method allows for direct measurement of the internal fit and marginal gap in both vertical and horizontal planes under microscope to minimizing the chance of repositioning errors. But this technique may result in some data lost during sectioning procedure.[4,5]

Profilometry: is a nondestructive technique. It gives the view of the die and the specimen in the same focal plane on the screen, so it's allow for an accurate focus. Using profilometry, the thickness of the cement layer at the marginal areas can only be indirectly estimated. Excessive care must be taken in repositioning the specimens, to prevent re-profiling discrepancies.[4]

Direct view (external microscopic examination): It is the most commonly used method for reproducible results. It's measure the gap between crown and die at the margin but not internally under a microscope at different magnifications. It's consider a cheaper and less time-consuming technique comparing to the other techniques and less chance of error occurrence that may result from multiple procedures. This method can be used only in vitro because it requires direct examination of marginal gap under high power microscopy for accuracy of this technique[4].

3D scanning method: 3D scanning techniques are able to produce 3D reconstructed images providing unlimited number of sections and points for linear measurements in different directions on 3D data sections. Also, 3D mapping of internal gap can be obtained. 3D reconstructed images can be obtained using optical scanners.[5]

Silicone weight technique: weighting the light body addition silicone is an easy method for evaluating the 3-dimentional internal fit of the crowns.[6]

SEM (scanning electronic microscopy): It allows the visualization of images at high magnification (50x – 10.000x and above). In this technique, an electron beam scans the surface of the sample to produce a variety of signals, the characteristics of which depend on many factors, including the energy of an electron beam and the nature of the sample, since a beam of electrons hit the sample and the response is collected by a detector.[7]

The accepted clinical range of marginal gap and internal fit?

There is no consensus on the clinically acceptable limits of the gaps. Sulaiman et al.[8] have stated that 100 µm is an acceptable gap for clinical use, while McLean and von Fraunhofer[9] have suggested that 120 µm should be the limit for clinical use. Moldovan et al.[1]0 reported that even a gap of 200–300 µm is acceptable. However, many researchers and clinical practitioners believe that the value of 120 µm is the most suitable limit for clinical use.

The effect of different CAD CAM system on marginal and internal fit

According to the fabrication methods CAD/CAM system can be divided to three groups:

- In office CAD/CAM
- In Laboratory CAD/CAM
- Centralized production

In 1971 Dr. Duret developing the first dental CAD/CAM system in France the system commercially known as Sopha. The major developments of dental CAD/CAM systems occurred in the 1980s. Dr. Mormann developed a new dental CAD/CAM system commercially known today as the Cerec system[11]. The marginal adaptation of restorations fabricated with the First digital impression systems available compared to the ones made with conventional impression methods showed relatively poor marginal adaptation[12]. Today several researches show there is an improvement in fitting quality of the CAD/CAM system.

Seok-Joon Ha and Jin-Hyun Cho [13] measured the marginal and internal fit of two different CAD/CAM systems (Ceramill and Zirkonzahn) using two non-destructive method weight and replica technique. The marginal discrepancy of Ceramill system was (101 and 131 µm) and Zirkonzahn system was (116-131 µm).

Reich et al.[14] studied the internal and marginal fit of four-unit zirconia posterior fixed dental prostheses fabricated by CAD/CAM (Lava system). After measurement of the marginal and internal fit under the optical microscope, the results were marginal gap; (91 ±58 µm) mid-axial gap; (98± 45 µm) and occlusal gap. (202 ±181µm) respectively.

Grenade et al.[15] measured the marginal and internal fit of single crown zirconia copings manufactured with a CAD/CAM system (Procera; Nobel Biocare) and a mechanized manufacturing process (Ceramill; Amann Girrbach). Using optical microscope to measure the marginal and internal fit, the result was: Procera group 51±50µm and 106 ±67 µm. And forCeramill group 81±66 µm and 115±59 µm.

Florain Beuer et al.[16] measured the marginal and the internal fit of three-unit posterior fixed partial denture with semi-sintered Zirconia block using different CAD/CAM systems laboratory CAD/CAM (Brain) and centralized CAD/CAM (Compartis). Under an optical microscope the mean marginal gap was 56.0 (±34.5) µm for Laboratory CAD/CAM, 51.7 (±45.2) µm for Centralized CAD/CAM, the internal gap for both systems are between 62.8 (±37.5) µm to 164.6 (±33.4) µm.

María et al [17], compared the marginal fit of zirconia copings fabricated with different systems CAD/CAM Cerec InLab and Zirkonzahn and a pantograph system Zirkograph 025 ECO. The marginal gap was measured using a stereomicroscope. The result was for Zirkonzahn (38.71 ± 12.62 µm), Zirkograph 025 ECO (77.92 ± 38.01 µm) and Cerec InLab (92.14 ± 38.59 µm).

Gonzalo et al[18], studied the changes in marginal discrepancies of posterior fixed dental prostheses of three zirconia systems manufactured using CAD/CAM technology and metal ceramic posterior fixed dental prostheses fabricated with the conventional lost-wax technique, before and after cementation. Divided into 4 groups Lava All-Ceramic System, Procera Bridge Zirconia, VITA In-Ceram 2000 YZ, and metal ceramic (control group). The result of the marginal discrepancy before and after cementation for Procera 9 ±10 µm and 12 ±9 µm. For lava 66±31 µm and71±45 µm. Metal ceramic 67±42 µm and 76±29 µm. YZ 40±19 µm and 48±15 µm.

Tolga Yucel et al[19], compared the marginal adaptation of crowns fabricated with four different all-ceramic systems Cerec 3, In-Ceram, IPS Empress 2, and Celay crowns. The marginal fit was evaluated under a stereomicroscope and image analysis program. The mean marginal gap on the gypsum dies was in Celay 21.5±4 µm. IPS Empress 2 29.3 ± 5 µm. Cerec 3 33 ±4 µm. In-Ceram crowns 74.6±10 µm. The mean marginal gap of crowns evaluated on the master steel die were in Celay 27.8±4 µm. IPS Empress 241.5±7 µm. Cerec 347.4±5 µm. In-Ceram crowns 94.9 ±10 µm.

Kohorst et al[20], studied the marginal fit and internal fit of four different CAD/CAM systems (InLab, Everest, Cercon and Digizon) to fabricate four-unit zirconia bridge frameworks. The horizontal and vertical marginal discrepancies and absolute marginal discrepancy were determined by means of a replica technique. The result of the absolute marginal discrepancy, horizontal and vertical marginal discrepancies were Digizon 57.9± 28.8 µm, 51.1± 26.1 µm and 23.8±18.8 µm. Cerec in lab 182.7± 26.1 µm, 85. ±27.1 µm and 111.5± 34.2 µm , Cercon 189.3± 10.5 µm,116.3± 31.1 µm and114.5± 32.1 µm Everest 206.3± 56.4 µm,37.6± 14.8 µm and197.3± 57.0 µm.

Denissen et al[21], studied the marginal fit of onlays fabricated with CICERO, CEREC, and Procera. The marginal fit measured under the microscopic digital imaging system. The result of marginal gap in Procera 68 ± 53 µm, CICERO 74±15 µm and CEREC 85± 40 µm.Sven Reich et al[22], studied the marginal and internal fit of three different CAD/CAM systems (Digident, lava and cerec in-lab) fabricated all-ceramic three-unit fixed partial dentures. Using the replica samples under the microscope to measure the marginal and internal fit. The result shown that the marginal gap in cerec in-lab 77 ±44 µm, lava80 ±50 µm and Digident 92 ±52 µm. Axial gap in Digident 105±51 µm, lava132 ±89 µm and cerec inlab 156±76 µm. Occlusal gap in lava 215±109 µm, cerec inlab 371±162 µm and Digident 383±179 µm.

AZAR et al [23], reported the marginal fit of lithium disilicate crowns fabricated using CAD/CAM and pressed ceramic approach. The marginal fit was measured using optical microscope. The marginal gap in CEREC (45 ± 12 µm) and Pressed (38 ± 12 µm).

Another study of Mohammed M. Beyari[24] compared the marginal and internal fit of all ceramic crown fabricated by in-office CAD CAM and Press-Laboratory technique. He reported that there was no significant difference between these two techniques and the average marginal gap for both fabrication process was below 63 µm.

The influence of different types of scanner on the marginal and internal fit:

The term ‘scanner' one understands, in the area of dentistry, data collection tools that measure three-dimensional jaw and tooth structures and transform them into digital data sets.[25] Digital scanner can eliminate time-consuming, human errors and the dimensional change of the impression materials and dental stone.[26]

Scanners are classified into:

A. Intra-oral scanners they are optical scanner "triangulation of light" and it's divided into two type single image and video cameras

B. Extra-oral "Laboratory" scanners it's has two types:

1. Optical scanners.

2. Mechanical scanner which can obtain 3D measurements by reading master cast mechanically line-by-line by means of a ruby ball for example Procera.[27] Table 1 present different types of scanner.

Scanner	Open close system	Acquisition technology	Powder require d	Color image	Imaging type
CERECO mnicom	Closed	White light	No	Yes	Filming
PlanScan	Open	Blue Laser	No	No	Filming
Trios Color	Open	Blue LeD	No	Yes	Photographing
Itero	Open	Red Laser	No	Yes	Photographing
True Definition	Open	Blue LED	Yes	No	Filming
CS 3500	Open	White LED	No	Yes	Photographing
Apollo DI(Sirona)	Closed	-	Yes	No	Filming

Table 1: shows different types of scanner

Chair-side CAD/CAM system has two types open system and close system, Kricheldorf et al,[28] compared the marginal adaptation between open and close system, the marginal gap for open group having the smallest mean (17.94 μm ± 4.77) and closed group having the higher mean (23.75 μm ± 3.05).

Some CAD/CAM system such as 3M Lava C.O.S., CEREC Bluecam require powder application such as titanium dioxide or magnesium oxide to produce matte finish and prevent reflections on surface during scanning, the matte finish improving detection of the finish line which improve the marginal fit. Marcel S et al, reported that there is an improvement in vertical fit of crowns and internal fit of the 3D luting space of when applying a powder (TDP) on the tooth surface before Omnicam scanning [29, 30]. Some study stated adding the powder layer on the tooth surface results in an increase thickness of 13-85μm and it will change the geometry of the surface and may affect the accuracy of the internal fit[29, 30]. The presence of saliva, blood, and thickness of the powder or movements of the patient can limits their accuracy.[29, 31]

Omar Ali.[29] compared the accuracy of five digital impressions (3M Lava C.O.S., 3Shape D900, Cadent iTero, CEREC Bluecam, and E4D Dentist). The accuracy was evaluated based on the mean difference and standard deviation in micrometers (μm.). The result was iTero (23 ± 3 μm), 3M Lava C.O.S (.36 ± 19 μm), 3Shape D900 (44± 18 μm), CEREC Bluecam (68 ± 12 μm) and E4D Dentist (84 ± 4 μm).

Yamamoto el al,[31] compared the marginal and internal cement thickness between single-image acquisition system (Bluecam Ver. 4.0) and a full-color video acquisition system (Omnicam Ver. 4.2). The marginal fit measured by microcomputed tomography. The result was for Omnicam groups: Mesial marginal cement thickness (159.00 ± 56.82μm), distal marginal cement thickness ± SD (212.00 ± 102.17 μm). and Internal cement thickness (242.00 ± 93.90μm) and for Bluecam group: Mesial marginal cement thickness ± SD (186.00 ± 70.02 μm), Distal marginal cement thickness ± SD (242.00 ± 130.53 μm) and Internal cement thickness ± SD (312.00 ± 75.68).

Al Hamad KQ et al.[32] studied the the fit of single crowns fabricated using conventional, digital, or cast digitization methods. Four groups were tested Group 1 (control): All-conventional group using 10 conventional impressions of the intraoral conditions,Group 2: 10 digital scans of the relevant 10 working casts using laboratory scanner (inEos X5) ,Group 3: 10 digital scans of the relevant 10 working casts using the intraoral scanner (CEREC Omnicam) and Group 4: All-digital group including 10 digital scans of the intraoral conditions using the intraoral scanner (CEREC Omnicam).the result was for the Marginal Group 1: (134.28± 22.96 μm), Group 2 (131.81 ± 24.48 μm) , Group 3 (125.46± 25.39 μm), Group 4 (135.59± 24.07 μm)and the result was for Internal fit Group 1 (141.12 22.58 μm) , Group 2 (143.06 19.26± μm), Group 3 (156.47 46.98± μm) and Group 4 (158.27 14.16± μm).

Renne et al.[33] evaluated and compared the trueness and precision of Seven digital impressions systems six intraoral scanners and one laboratory scanner in both sextant and complete-arch scenarios. CEREC Omnicam (CO), CEREC Bluecam (CB), Planmeca Planscan (PS), Cadent iTero (IT), Carestream 3500 (CS), 3Shape TRIOS 3 (ST), 3Shape D800 model scanner (SD). Precision describes how close repeated measurements are to each other. Therefore, a scanner with higher precision correlates to a more repeatable and consistent scan. Describes how far the measurement deviates from the actual dimensions of the measured object Therefore, a scanner with high trueness indicates that the scanner delivers a result that is close or equal to the actual dimensions of the object being scanned. Furthermore, time of scanning was evaluated and correlated with trueness and precision. The result for sextant scanning, the Planscan was found to be the most precise and true scanner while the 3Shape Trios was found to have the poorest for sextant scanning. And conclude for complete-arch scanning, the 3Shape Trios have the best balance of speed and accuracy. The order of trueness for complete arch scanning was as follows: 3Shape D800 >iTero >3Shape TRIOS 3

>Carestream 3500 >Planscan >CEREC Omnicam >CEREC Bluecam. The order of precision for complete-arch scanning was as follows: CS3500 >iTero >3Shape D800 >3Shape TRIOS 3 >CEREC Omnicam >Planscan >CEREC Bluecam.

Hack et al.[34] studied the accuracy of six intraoral scanners (iTero,True Definition, PlanScan, CS 3500, TRIOS and CEREC AC Omnicam) the result for the accuracy were evaluated for trueness and precision values. The trueness measurements for the TRIOS (6.9 ± 0.9 µm), followed by the CS 3500 (9.8 ± 0.8 µm), the iTero (9.8 ± 2.5 µm), the True Definition (10.3 ± 0.9 µm), the PlanScan (30.9 ± 10.8 µm), and the CEREC OmniCam (45.2 ± 17.1 µm).

The Precision values measurements for the TRIOS (4.5 ± 0.9 µm), followed by the True Definition (6.1 ± 1.0 µm), the iTero (7.0 ± 1.4 µm), the CS3500 (7.2 ± 1.7 µm), the CEREC OmniCam (16.2 ± 4.0 µm), and the PlanScan (26.4 ± 5.0 µm).

Shembesh et al. [35] studied marginal fit of 3-units zirconia fixed dental prostheses obtained from intraoral digital scanners (Lava True Definition and Cadent iTero), and compare it to scanning of a conventional silicone impression, and the resulting master cast with an extraoral scanner (3Shape lab scanner). The marginal fit was measured using an optical comparator the result form smallest to highest Lava True Defintion (26.6 µm), stone cast scan (50.2 µm), Cadent iTero (62.4 µm) and PVS impression scan (81.4 µm).

Su TS et al.[36] compared the marginal fit and internal fit for 3-unit ceramic FDP frameworks obtained from Trios intraoral digital impression and conventional impression. The marginal fit and internal fit was evaluted using optical microscopy with ×50 magnification. The smallest marginal and internal gap was for intraoral digital impression (64 ±16 µm), (111 ±34 µm) and the conventional impression was higher (76 ±18 µm), (132 ±44 µm).

Shinyoung et al.[37] compared marginal fit of zirconia coping obtained from different impression: the conventional impression group (CI), iTero with polyurethane die group (iP) and stereolithography files iTero with no dies (iNo), the higher marginal gap was for iNo group (103.55±16.50 µm) followed by iP group(103.05 ±14.67µm) and the smallest maginal gap was for CI group (92.67±13.94 µm) all of the groups were clinically acceptable.

Abdel-Azim et al.[38] compared the marginal fit lithium disilicate single obtained from conventional with polyvinyl siloxane impression and two intraoral scanners (Lava COS& iTero). The marginal gap was measured with a stereomicroscope. The marginal gap was higher in conventional impression (112.3 ±35.3 µm) compared to the digital impression Lava (89.8 ±25.4µm) and iTero (89.6 ±30.1 µm).

Berrendero1 et al.[39] compared the marginal and internal fit of all ceramic crowns fabricated from conventional silicone impressions and intraoral scanner (Trios). Marginal and internal fit measured under stereomicroscopy ×40. The result of the marginal and internal fit was (106.6 ±69.6 µm), (170.9 ± 119.4 µm) for digital impression and (119.9 ±59.9 µm), (185.4 ± 112.1 µm) for conventional impression respectively. Syrek et al. [40] compared the marginal fit of all ceramic crowns obtained from intraoral Scanner (Lava C.O.S.) and conventional silicone impression. The marginal fit was clinically evaluated by replicas technique, the result was (71 µm) for conventional impression and (49 µm) for digital impression.

Neves et al.[41] compared the marginal fit for lithium disilicate crowns fabricated by CAD/CAM system with two different intraoral scanners (The Cerec 3D Bluecam scanner and E4D Laser scanner) and compared to heat-pressing technique. The marginal fit evaluated with micro-computed tomography. The vertical misfit from smallest to the highest heat-pressing 36.8±13.9 µm, Cerec 3D Bluecam 39.2 ±8.7 µm, then E4D 66.9 ±31.9 µm.

SHIMIZU et al.[42] compared the accuracy between extra-oral scanner (active triangulation) and two different intra oral scanner (active triangulation and confocal laser). Using coordinate measuring machine as a measurement method shown that extra-oral scanner generates better than the intra oral scanner. The researcher found that the marginal gap was 6 µm for the extra-oral scanner and 9 µm for the intra-oral scanner which is clinically acceptable.

In contrast an in vitro study of PEDROCHE et al,[43] compared the fitting of zirconia coping using intra scanner of a human mandibular first molar and two different method of extra oral scanner (scanning of polyvinyl siloxane impressions and scanning of the gypsum cast) using silicone replica technique to evaluate the marginal and internal fit. The marginal gap of intra-oral scanner was the lowest value (59.2±14.3µm), gypsum model scanning showed higher gap values (87.0±31.0 µm), and polyvinyl siloxane impression scanning was (71.1 ± 19.1 µm). All the reading was with clinically accepted range.

The influence of design software on marginal and internal fit:

Special software is provided by the manufacturers for designing various kinds of dental restorations. With such software, crown and fixed partial dentures frameworks can be constructed. On the other hand, some systems also offer the opportunity to design full anatomical crowns, partial crowns, inlays, inlay retained FPDs, as well as adhesive FPDs and telescopic primary crowns.[25] Few studies have assessed their effect on marginal and internal adaptation of crown restorations.

Ji Suk SHIM et al.[44] reported that the fit of a crown restoration can be affected by the specific CAD/CAM software version and by the parameter settings selected, even if the same scanner and milling machine were used. The study compared between versions 3.8 and 4.2 of the software, and the spacer parameter was set at either 40 µm or 80 µm. The result was crowns designed with the version 4.2 of the software showed a better fit than those designed with version 3.8.

The influence of different fabrication process:

The two primary methods used to fabricate these restorations are subtractive (milling and grinding) or additive manufacturing (Rapid Prototype, RP or 3D printing). Subtractive technology it's processes in which power-driven machine tools, such as Saws, lathes, milling machines, and drill presses, are used with a sharp cutting tool to mechanically cut the material to achieve the desired geometry with all the steps controlled by a computer program.[45] The type of restorations that used are large solid blocks. The milling units classified into two categorized according to: (A) dry/wet/milling and grinding or (B) number of axes. The main disadvantage of milling technology is any surface details less than the diameter of the milling bur will be over milled and will cause loose fit of restoration27 and it is cause waste of materials.

Additive manufacturing process works by taking a 3D computer file and creating a series of cross-sectional slices. Each slice is then printed one on top of the other to create the 3D object[45]. The main problem it can cause differences in the final model production because of shrinkage during building, post-curing, and minimal thickness of the layers.27 This method does not waste unnecessary materials. The sintering is performed by selectively focusing a laser beam on the selected part of the material only the desired part of the product is obtained.[46] additive manufacturing technologies include Stereolithography (SLA), Fused deposition modeling (FDM). Selective electron beam melting (SEBM), Laser powder forming and Inkjet printing.[45]

Koutsoukisin et al.[47] reported that selective laser melting manufacturing technique provides different microstructure from casting and milling with minimal internal porosity and internal fitting, marginal adaptation, and comparable bond strength to porcelain.

Dong-Yeon Kim et al.[48] compared the marginal and internal fit of cobalt–chromium (Co–Cr) alloy copings fabricated using lost wax technique (LW), subtractive manufacturing: wax block (WB), soft metal block (SMB) and additive manufacturing microstereolithography (m-SLA), and selected laser melting (SLM) techniques. The marginal and internal gap measured under digital microscope (160 x).

The result in the marginal, axial wall, and occlusal gaps were: LW group 91.8±80.9 µm, 83.4 ±41.7 µm and 163 ±78.1 µm. WB group 94.2±77.1 µm77.5 ±39.1 and 122± 77.3 µm. SMB group 60.0± 26.6 µm, 79.4± 25.5 µm and 90.8±39.5 µm. M-SLA Group 154± 76.0 µm, 72.4 ±44.1 µm and 258± 67.9 µm. SLM group 239±126 µm, 73.6 ±25.5 µm and 384±67.8 µm.

Dong-Yeon Kim et al.[49] reported the marginal and internal fit of three-unit metal framework of fixed dental prostheses fabricated using lost wax technique (LW), subtractive manufacturing (SM) and additive manufacturing (AM). The marginal and internal fit measured using a silicone replica technique and the digital microscope. The result of the marginal gap, axial wall gap, and occlusal gaps were in LW group 59.03±37.49 µm, 102.25± 36.01 µm and137.37±53.10 µm. SM group 50.09 ± 34.76 µm, 87.20 ±38.95 µm and138.34± 44.15 µm. AM group 107.27 ± 61.33µm, 103.44 ±39.99 µm and 238.16± 86.72 µm, respectively.

Shamseddine et al.[50] compared marginal and internal fit of lithium disilicate crowns fabricated using subtractive milled wax pattern and the microstereolithography additive wax. The replica technique was used to measure the fit under scanning electron microscopy at (×80). the result of the marginal gap, axial wall, and the occlusal gap of the milled technique were 105.1±39.6 µm, 98.1 ±26.0 µm and 199.0 µm, respectively. For the additive technique were 126.2±25.2 µm,106.8 ±21.2 µm and 257.2 µm, respectively.

Ki-Baek Kim et al.[51] studied marginal fit of fixed dental prostheses fabricated with the subtractive method (milling soft metal blocks SMB), additive method (selective laser sintering SLS) and traditional method (lost wax and casting LWC). The marginal gap measured using the 3-dimensional technique. The marginal gap was 32.6±4.8 µm in SMB group, 47.3 ±8.6 µm in SLS group and 64.1 ±14.2 µm in LWC.
Dan Xu et al.[52] compared the marginal fit of cast cobalt-chromium alloy crowns and the fit of selective laser melting fabricated crowns. The marginal gap evaluated under stereomicroscopy (x100). The result of marginal gap was 102.86 ±40.54 µm in SLM group and 170.19 ±66.17 µm in cast group.

Huang et al.[53] compared the marginal and internal fit of Selective laser melting metal ceramic crowns SLM Co-Cr with 2 lost-wax cast metal ceramic crowns, cast Au-Pt and cast Co-Cr alloy. The marginal and internal fit measured under stereomicroscope at ×30 magnification. The result of the marginal gap of the SLM Co-Cr group (75.6 ±32.6 mm) was not different from the cast Au-Pt group (76.8 ±32.1 mm) but shown better adaptation than the cast Co-Cr group (91.0 ±36.3 mm). The mean occlusal gap width of the SLM Co-Cr group (309.8 ±106.6 mm) was significantly higher than that of the cast Au-Pt group (254.6 ±109.6 mm) and the cast Co-Cr group (249.6 ±110.4 mm).

Homsy et al.[54] compared the marginal and internal fit accuracy of lithium disilicate glass-ceramic inlays fabricated with a conventional, milled, and 3-dimensional (3D) printed wax patterns. Five groups of 15 inlays were obtained through conventional impression and manual wax pattern (group CICW); conventional impression, laboratory scanning of the stone die, CAD-CAM milled wax blanks (group CIDW) 3D printed wax patterns (group CI3DW); and scanning of the master preparation with intraoral scanner and CAD-CAM milled (group DIDW) or 3D printed wax patterns (group DI3DW).

The marginal and internal gap measured with the replica technique using a stereomicroscopy. The result in the marginal and internal gap were in CICW group (45.1 ±6.7 µm) and (78.0 ±15.5 µm.). CIDW group (37.6 ±10.5 µm) and (83.7 ±16.2 µm). CI3DW group (39.8 ±8.7 µm) and (82.9 ±11.8 µm). DIDW group (24.8 ±3.1 µm) and (71.9 ±7.5 µm). DI3DW group (39.7 ±6.7 µm) and (88.8 ±14.5 µm).

S Gunsoy and M Ulusoy.[55] reported the internal and marginal fit of chrome cobalt prosthesis on premolar and molar using different four concept: Conventional lost wax method, milled wax with lost-wax method (MWLW), direct laser metal sintering (DLMS), and milled Co-Cr (MCo-Cr). After measuring the film thickness of the marginal and internal gaps using stereomicroscope, the outcome of this result was direct laser metal sintering has the lowest internal and marginal gap (65.84 µm for premolar and 58.38 µm for molar) and the other techniques were with the clinically accepted range.

Other factors effecting the marginal and internal fit in CAD CAM fabrication

Effect of preparation geometry

Souza RO et al[56], studied the marginal and internal fit for ceramic crowns fabricated by CEREC in Lab CAD/CAM with different finish lines (TC: tilted chamfer; LC: large chamfer; RS: rounded shoulder). The marginal and internal gap measured with optical microscope (250×). The result in the RS group (28.24 ± 11.42 µm) showed significantly lower marginal discrepancies values (p = 0.001) than those of TC (99.92 ± 18.32 µm) and LC (64.71 ± 25.64 µm) groups. The internal discrepancies results demonstrated significantly lower values in the LC group (183.01 ± 62.82 µm) than those of TC (216.26 ± 83.23 µm) and RS (219.12 ± 87.24 µm) groups.

Beuer et al [57], evaluated the effects of different preparation angles on the precision of fit of zirconia crown frameworks. Dies were fabricated with three different preparation angles: 4, 8, and 12 degrees total taper. Each tapering angle were fabricated by a laboratory and a milling-center CAD/CAM system (Cercon). Result was for copings fabricated by the laboratory CAD/CAM system, the mean (SD) marginal openings were 37.5 (37.0) µm in the 4-degree group, 42.3 (44.4) µm in the 8-degree group, and 36.8 (30.9) µm in the 12- degree group. For copings fabricated by the milling center system, the mean (SD) marginal openings were 45.5 (35.7) µm in the 4-degree group, 36.6 (28.9) µm in the 8-degree group, and 40.3 (37.2) µm in the 12-degree group.

Jalali et al.[58] compared the marginal adaptation of zirconia-based all-ceramic restoration with two preparation designs. The conventional group received a peripheral shoulder preparation and the modified group received a buccal shoulder and proximal/lingual chamfer preparation. The marginal fit of the zirconia crowns (Cercon) was evaluated using a stereomicroscope. The mean marginal gap was 71±16µm in the conventional group and 80±10µm in the modified group.

According to Tsitrou et al.[59] the marginal fit of resin composite crowns manufactured with the CEREC 3 system employing three different margin designs; bevel, chamfer and shoulder, by means of a replica technique and a luting agent. The result of marginal gap using replica technique were Bevel Group 105± 34µm, Chamfer Group 94 ± 27 µm a Shoulder Group 91± 22 µm. And for the resin composite cement the average marginal gaps were: Bevel Group 102 ± 28 µm, Chamfer Group 91± 11 µm and Shoulder Group 77 ± 8 µm.

The effect of long span on fabrication of CAD CAM prosthesis

A vitro study of Chuchai Anunmana et al.[60] to compare the marginal and internal fit of single crown and three unit of fixed partial denture on second premolar and second molar using Lava system. The outcome of this study shown that there was a significant difference between single crown and three units FPD for single crown premolar teeth were 150.5 ± 0.5 µm and molar teeth were 146.5± 0.4 µm and for three units FPD of premolar and molar 154.5 ± 0.4 µm, 211.5 ± 0.4 µm respectively.

The influence of CAD CAM materials on marginal and internal fit

Types of CAD/CAM Materials

There are several CAD/CAM materials to choose from, all designed to provide efficient restoration design and production. A variety of materials are available in block form, including glass ceramics, resin Nano ceramics, zirconia, ceramic composites, ceramics and resin composites. The materials are also classified according to the technique (chair side or laboratory).

Chairside CAD/CAM Materials: Chair-side CAD/CAM restorations can be fabricated from different materials which are suitable for this technique, they are predictable and durable. All blocks are either monochromatic or polychromatic form for chair-side CAD/CAM restorations.

These block materials have strength, high-quality, and excellent esthetics. Their properties are superior to the traditional materials. All recent developments in CAD/CAM materials are concerned with high strength and simplicity. The Computer-aided manufacturing procedures will change many aspects of dentistry in the future, especially with the regard to treatment simplicity and production period. Therefore, clinicians and technicians must be aware of the advantages and disadvantages of computer-aided manufacturing while such procedures continue to develop and become an integral part of dentistry. [61]
Kusai Baroudi and Shukran Nasser [61], classified some chairside CAD/CAM restorative materials:

- Feldspar-based ceramic Vitablocs Mark I (Vident)
- High-glass–feldspar-based ceramic Vitablocs Mark II (Vident)
- Resin-based composite Paradigm MZ100 blocks (3M ESPE)
- Paradigm C (3M ESPE)
- Lithium disilicate glass ceramic (IPS e.max CAD, Ivoclar Vivadent) for anterior or posterior crowns, implant crowns, inlays, and onlays or veneers

1-Feldspar-based ceramic

Dennis J. Fasbinder.[62] published that Vitablocs Mark II (Vident) and CEREC Blocks are feldspathic glass ceramics. Both materials are fine-grained, homogeneous feldspathic porcelain with an average particle size of 4 µm. The small particle size allows for a high-gloss finish and minimizes abrasive wear of the opposing dentition. Introduced in 1991, Vitablocs Mark II is available in the 10 most common Vita 3D-Master shades.
Triluxe blocks (Vident) contain three different bands of color to recreate the shade and translucency of the tooth from cervical to incisal. Triluxe Forte blocks (Vident) feature a gradient of color and translucency from cervical to incisal with increased fluorescence and chroma in the cervical area.

2-Resin-based composite Paradigm MZ100 blocks:With three years of proven clinical performance, MZ100 composite blocks are the only radiopaque composite blocks available Paradigm MZ100 (3M ESPE) was introduced in 2000.Kusai Dennis J. Fasbinder [61] , stated that it has zirconia-silica filler particles and is 85% filled by weight with an average particle size of 0.6 µm. It is radiopaque and available in six shades, as well as a more translucent enamel color. Composite can be more easily adjusted and polished intraorally compared to ceramic materials. This is an important feature of the chairside clinical technique because there is generally no working die and occlusal refinement occurs intraorally.

The following are some properties of this material:

- High flexural strength and fracture toughness
- Enamel-like wear characteristics are superior to that of ceramic blocks
- Easy to finish and polish
- Can be easily characterized with light-cured composite stains and glazes
- An ideal material for CAD/CAM where strength and occlusal wear properties are needed
- Easy to repair intraorally
- Indicated for inlays, onlays, crowns and veneers

3-Leucite reinforced glass ceramic material Paradigm C (3M ESPE).

It was presented by Dennis J. Fasbinder [62], that Paradigm C blocks are the newest addition to the Paradigm line of blocks. These radiopaque restorations are virtually undetectable due to the good shade match and natural esthetics of the material with surrounding tooth structure. Created from leucite-reinforced glass ceramic material

- Well-balanced translucency and fluorescence
- Provides a chameleon effect for good shade matching
- Easy to polish
- Can be stained and glazed to provide characterization
- Indicated for Inlays, Onlays, Crowns and Veneers

4-Lithium disilicate glass ceramic
Lithium disilicate was introduced by as Empress II in 1998. Initially, the material was too opaque for full-contour restorations, so a layering porcelain had to be baked over the substructure.
Andrew Koenisberg.[63] proclaimed that it is now available in various translucencies, making it
appropriate for all single-crown and veneer applications, as well as three-unit bridges up to the bicuspid region. It is also available for custom implant abutments and screw-retained implant crowns. There is excellent data on its durability and it can be custom stained and layered. While, it can be cemented with conventional cements, it also has excellent adhesion to composite cements. These materials are often the best choice for single-unit restorations anywhere in the mouth and anterior three-unit bridges.

CAD/CAM materials used in lab

Zirconia

The following is the description of zirconia in a journal, Inside Dentistry, by Andrew koenisberg[63] it is one of the main materials used in the laboratory. Zirconia was originally a substructure material because of its lack of translucency and its opaque color. Zirconia potentially has the flexural strength of metal. While it can be layered with translucent porcelain, there have been issues with chipping. There are now multilayer discs so that the restorations have more Chroma at the gingiva and more translucency at the incisal, reducing the need to layer. Typically, the more esthetic the zirconia, the weaker it is, though even the weaker materials exceed the strength requirement for anterior bridges [63]. Advantages include strength and conventional cementation, while disadvantages are difficulty in chairside adjustment and modification.

Atousa Azarbal et al. [64] compared the marginal fit of CAD/CAM copings milled from hybrid ceramic (Vita Enamic) blocks and lithium disilicate (IPS e.max CAD) blocks, and to evaluate the effect of crystallization firing on the marginal fit of lithium disilicate copings. A Macroview Microscope (14×) was used for direct viewing of the marginal gap. The mean marginal gap for the lithium disilicate group before firing was 70.07µm, while the mean marginal gap of hybrid ceramic group was 47.91µm. Greater mean marginal gaps were measured for crystallized lithium disilicate copings. The overall mean difference in marginal gap before and after firing (precrystallized and crystallized lithium disilicate copings) showed an average of 62µm increase in marginal gap after firing.

Yujl Kukubo et al. [65] measured the marginal and internal gaps of Nobel Procera crown zirconia were clinically evaluated using silicone materials. The results showed the mean marginal and internal gaps of 91 crowns at the four measuring points. The mean marginal gap of Nobel Porcera crown zirconia was 44.2mm, which was the smallest among all reference points. The rounded shoulder and occlusal area tended to have larger gaps.

Moritz Zimmermann et al. [66] conducted a study using three different CAD/CAM materials (each n=10): zirconia-reinforced lithium silicate ceramic (Celtra Duo; CD), leucite-reinforced silicate ceramic (Empress CAD;EM), resin Nano ceramic (Lava Ultimate; LU). A 3D digital measurement technique using an intraoral scanner was used to measure the difference in fit between the three materials for a master endo crown preparation. Results varied from smaller marginal gap 88.9±7.7µm of resin. Nano ceramic restorations to the larger 182.3±24.0µm for occlusal fit of zirconia-reinforced lithium silicate restorations.

Discussion

In this review article we collected several published studies regarding the fitting quality of prosthesis manufactured by CAD/CAM system. Each step in CAD/CAM system has influence in the adaption of the prosthesis. Starting from CAD/CAM system using different systems as (in-office, in-lab, Centralized production) to fabricate a dental prosthesis has no significant effect on the marginal fit. Several studies compared the marginal fit between CAD/CAM systems with other techniques as pressed technique. According to two studies of AZAR et al and Mohammed M. Beyari pressed technique was superior compared to CAD/CAM system in the marginal fit with minimum difference.[23,24]

Shifting to the types of scanner that used in CAD/CAM system and their influence on the adaption of prosthesis. Using intra-oral scanner provide better marginal adaption compared to extra-oral scanner. In contrast, a study of SHIMIZU et al. proves that extra-oral scanner has smaller marginal gap (6 µm) than intra-oral scanner (9 µm).42 Several studies have suggested that intra-oral scanner can overcome the conventional impression technique on the marginal and internal fit.[36,39,40]

The design software of CAD/CAM system has an impact on the marginal adaption of prosthesis using latest version of software conduct a smaller marginal gap.[44] Subtractive and additive manufacturing are the primary methods used to fabricate a dental prosthesis. Despite the advantages of additive technique, it has poorer marginal fit compared to the subtractive technique. According to several studies suggested that subtractive technique has smaller marginal gap than additive technique.[48,49,51]

In addition, preparing a tooth with different preparation geometry, length of the span, and different uses of CAD/CAM material have an impact on the adaption of dental prosthesis. Despite of these factors, most of the studies shown that the marginal and internal discrepancies of a prosthesis fabricated with CAD/CAM system is clinically acceptable.[13,17,18,19,20, ,24]

However, Due to various outcome of the studies make it difficult to determine which system or scanners provides the best marginal and internal adaptation. Also, using different methods to measure the marginal adaption can influence the reading of the marginal gap. In addition, most of these studies were in vitro studies tested under ideal conditions, that's not reflect the clinical environment such as presence of saliva or blood and restricted mouth opening which can limit the accuracy of digital oral scanner. Further studies are necessary to assess the fit accuracy of CAD/CAM restorations under clinical conditions.

Conclusion

In the last recent years there is a huge improvement in the marginal adaption of CAD/CAM prosthesis make it overcome the conventional technique.[49] Scanners, milling machine, preparation geometry and types of materials may affect the marginal and internal adaption. However, various studies proved that CAD/CAM can produce fixed prosthesis with a marginal gap below 120 µm that consider clinically acceptable.[17,18,19,20, 24]

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