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Assessment of Vertical Marginal Gap of Nano-lithium Disilicate Occlusal Veneers Using Two Different Fabrication Techniques after Thermocycling

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Abstract

Background: Assessment of the vertical marginal gap of Nano-Lithium Disilicate occlusal veneers using two different fabrication techniques after thermocycling.

Methods: One maxillary first premolar of typodont acrylics samples was selected for standardized preparation of occlusal veneers. Samples were scanned using an extra-oral scanner and prepared to receive occlusal veneers using Exocad software following standard preparation guidelines for ceramic occlusal veneers. Biogeneric copy was done for all samples. Samples were divided into two groups according to fabrication of Nano lithium Disilicate (Group I) pressing technique (n= 14), and (Group II) milling technique (n=14). 1mm thicknesses chamfer finish line design with proximal extension preparation. All designs were done by using a digital software program. Samples were cemented using self-adhesive resin cement, and thermocycling was done (10,000 cycle), followed by measurement of the vertical gap using stereomicroscope (X35) and image software analysis, with 14 measurement points taken per specimen.

Results: One-way ANOVA showed Group (I) pressed veneers (20.40±1.94) (µm) had a lower marginal gap than Group (II) milled veneers (23.66±5.74) (µm), yet the difference was not statistically significant (p=0.095). Pressing technique showed non-significant superior results than milling regarding marginal adaptation.

Conclusion: Marginal adaptation of all occlusal veneers with different fabrication techniques used in this study showed clinical acceptance results within clinical acceptance range < 120 µm. Occlusal veneers fabricated with CAD/CAM and pressing technology showed clinically comparable vertical margin adaptation.

1 Introduction

Teeth wear, attrition, erosion, physiological variables, and chemo-mechanical factors contribute to the loss of natural tooth structure on the occlusal surface. Abnormal occlusion results in diminished function and, ultimately, a compromise in aesthetics due to the degradation of dental anatomy. This sequence can lead us to conventionally preparing the entire crown, which could be destructive to the tooth structure. [1,2] The restorative treatment should be guided by the severity of the damage to prevent further deterioration. [1]

Minimally invasive dentistry is presently an important subject in clinical restorative dentistry, due to the progress of adhesive bonding procedures. The durability of teeth and restorations is now achievable with more conservative methods. [3]

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Occlusal veneers are extracoronal restorations characterized by a minimally invasive preparation design for badly worn teeth, and they are adhesive-retained restorations that entirely cover the occlusal surface. [4] The primary advantage of occlusal veneers is the restoration of mastication while preserving significant dental structure. The ideal thickness for occlusal veneers, considering the manufacturer's guidelines for different ceramic materials, typically varies from 1 to 1.5 mm for optimal mechanical and optical characteristics. [5]

Occlusal veneers are fabricated through various procedures, each with different advantages and disadvantages: the pressing technique involves making a wax model of the veneer design, investing it in a mold under pressure, and subsequently pressing molten ceramic material into the mold to achieve the required form. This approach exceeds CAD/CAM milling in terms of marginal fit [6], allowing the production of veneers with a more natural aesthetic, enhanced precision, reduced porosity, and remarkable strength attributed to the crystallization structure formed throughout the process. The CAD/CAM procedure involves scanning the prepared tooth with a digital scanner, designing the veneer on a computer, and subsequently machining the veneer from a block of ceramic material using a CAD/CAM machine. The technology provides exceptional precision and predictability, allows a wide variety of ceramic materials, and allows same-day restorations due to reduced processing times. [7]

Lithium disilicate ceramics are widely used glass ceramics for partial crowns, onlays, and inlays. These restorations, along with other ceramic materials, are recognized for their suitability as enamel substitutes. Lithium disilicate is one of the strongest glass ceramics, exhibiting exceptional mechanical properties, including high flexural strength and superior aesthetics achieved through different manufacturing techniques. [8]

Nano-lithium disilicate (NLD) is a material characterized by its own unique nanostructure and processing properties. The translucency can be modified during crystallization, and it is typically regarded as possessing excellent strength and toughness. Nanostructured materials are materials characterized by structures or dimensions within the range of 1–100 nanometers. Nano-scaled fillers offer enhanced aesthetics, exceptional polishability, and elevated strength. [9]

NLD is recognized for its increased flexural strength (300-400 MPa) and fracture toughness (2.8-3.5 MPa m1/2). It also demonstrates superior optical characteristics, including variable translucency depending upon the crystallization process. The crystallization process in NLD processing enables control of translucency, a crucial aesthetic element in dental applications. NLD is often used in dental restorations, including crowns, bridges, and inlays, owing to its strength, durability, and aesthetic qualities. [10]

Research indicates that NLD materials exhibit a high survival rate in dental restorations, with a minimal occurrence of mechanical failures such as debonding, fractures, and chipping. NLD is a glass-ceramic substance, indicating it consists of both a glassy and a crystalline phase. The crystalline phase comprises lithium disilicate, enhancing the material's strength and durability. [11]

Due to their exceptional mechanical and translucent properties, these ceramics offer a more precise and successful approach to attaining a natural smile, whether through pressing or milling. Nano-lithium disilicate (Amber) ceramics, using nanotechnology, represent a highly promising material. [12] The marginal gap is a fundamental criterion for the long-term success of ceramic restoration. [13] A rise in marginal discrepancy will impact the cement, causing it to break down faster, which will harm the periodontal ligaments and the tooth under the restoration, leading to cavities and eventually the failure of the restoration. [14]

This study aimed to assess the marginal gap of two different fabrication techniques (pressing and milling) following thermocycling using Nano-lithium disilicate ceramic material. The null hypothesis will be there will be no significant difference regarding the vertical margin adaptaion of two fabrication techniques (milling and pressing technology).

2 Materials and Methods

2.1 Ethical Approval

The method employed in this study was approved by the research ethical committee (Faculty of Dentistry - MSA University). The research was exempted from the review of the Research Ethics Committee since the research subjects are artificial material not human or animal specimens. (Ethical approval no: 852).

2.2 Sample size calculation

A power analysis was designed to have adequate power to apply a 1-tailed statistical test of the research (null hypothesis) that there is no difference between tested groups regarding the marginal adaptation gap of the bonded occlusal veneers constructed from Nano-Lithium disilicate (Amber) using two different fabrication techniques (pressing and milling). A sample size of 14 in each group was obtained by adopting an alpha level of (0.05), a beta of (0.2) i.e. power = 80%), and an effect size (f) of (0.739) based on the results of a previous study. [15] The predicted sample size (n) was found to be a total of 28 samples. Sample size calculation was performed using G*Power version 3.1.9.7.

2.3 Samples selection

Not needed as the study will be done on typodont mode..

Inclusion Criteria:

Occlusal veneers preparation should follow guide lines Teeth without soft tissue remnants or calculus.

Exclusion Criteria:

Prepared samples not following guide lines

2.4 Scanning and designing with centralization of the typodont mode inside the base block:

The standard triangular language (STL) file of the typodont sample was used with a digital software system (exocad DentalCAD, exocad GmbH, Germany) following the scanning of the typodont model using an extra-oral scanner (3Shape scanner, Generation Red E3 lab scanners, Denmark) to guarantee precise, nearly vertical alignment of the long axis of each parallel to the long axis within the base block mold. The dental model was positioned 2mm beneath the cemento-enamel junction (C.E.J.) to fabricate the 3D-printed block model. The construction of a socket facilitated the positioning and securing of a typodont model. Following the socket preparation, the 3D printing blocks were produced with a 3D printing device (Creality HALOT-MAGE PRO Resin 3D Printer, China) with liquid resin (PROSHAPE DIGITAL SOLUTION Temp Resin, Turkey).

2.5 Preparation Design

All samples were prepared using the exocad digital software system with the same STL file to standardize preparation and to regulate the thickness and geometry of restorations by biogeneric copying. Each occlusal veneer was calibrated to possess a consistent thickness of 1-1.5 mm on the occlusal surface. The screen exhibited the image of the scanned die. To facilitate design, the scanner software incorporated a captured image and a biogeneric virtual copy catalog, enabling the creation of a biogeneric replica by scanning the sample prior to initiating the virtual preparation design. This process aims to automatically generate a custom, lifelike restoration that accurately reflects the original dental morphology. The chamfer finish line design starts with preparing the occlusal surface in accordance with occlusal anatomy, lowering it by 1.5 mm at the cusp tip and 1 mm at the fossa with a 1mm circumferential chamfer finish line positioned 2 mm above the height of contour (**Fig. 1)**. The preparation was evaluated using the preparation analysis tool, and following the selection of the necessary anatomy and extension of the occlusal veneer, the design was preserved for 3D printing.

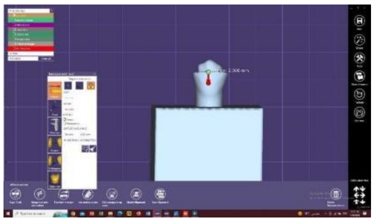

Figure 1. Chamfer finish line preparation checked by preparation analysis tool.

2.5.1 Printing phase of model preparation

The 3D model of the prepared typodont teeth within the block, featuring one preparation design, was produced using stereolithography for 3D printing (Creality HALOTMAGE PRO Resin 3D Printer, China). It was extracted from the printing platform for post-processing. The model underwent two washes in 99% isopropyl alcohol and was subsequently cured in a UV light chamber (Wash& Cure 3.0 Plus, Anycubic, China) emitting a wavelength of 405 nm to initiate the epoxy fabrication process and replicate the design model.

2.6 Occlusal veneers fabrication

2.6.1 Fabrication of occlusal veneer by pressing technique

The process of fabricating occlusal veneers involves selecting an image from a software design and adapting a CAD/CAM PMMA template of a pre-fabricated disk (YAMAHACHI DENTAL, Japan) **(Fig. 2)**. They were used to produce pressed nano-lithium disilicate (Amber) restorations via milling machine (Vhf K5 five-axis dry milling machine, Germany). A wax sprue is attached to the PMMA preparation template for investment, which uses phosphate-bonded investment material (Bellavest SH; Bego).

A digital gram scale (Metro Electronic Pocket Scale) is used to choose the correct size of ingot needed for the veneer. Next, a sprue attaches the PMMA veneers to the ring base. The investment material is then placed in a heated furnace (Vulcan A 130; DENTSPLY Sirona) according to the manufacturer's instructions and burnedut in the furnace at 850°C. Ceramic Amber is inserted into the investment ring, and the assembly is placed in the center. The pressing furnace (Programat EP3000; Ivoclar Vivadent AG) presses the nano-lithium disilicate ceramic ingots. Following the manufacturer's instructions, we divest, finish, and polish the ingots after an hour.

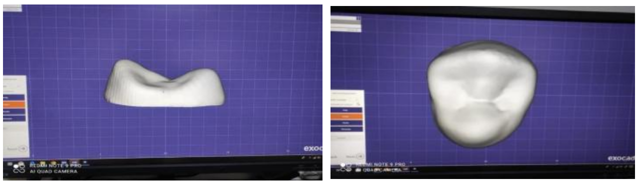

Figure 2. CAD/CAM PMMA design for chamfer finish line preparation

2.6.2. Fabrication of occlusal veneer by CAD/CAM milling technique

A 5-axis milling machine (CORiTEC® 350i PRO+, Germany) was used to produce the occlusal veneers after securing the milling block within the tray. One is related to the chamfer finish line design. A tapered round-end diamond bur from the milling chamber machine was utilized to contour the occlusal surface, in accordance with occlusal anatomical principles.

2.6.3 Firing protocols

Amber occlusal veneers receive cleaning in an ultrasonic cleaner before crystallization in the ceramic furnace (Programat EP3010 Ivoclar Vivadent, Zürich, Switzerland). The firing procedure started with a pre-saved firing program once the occlusal veneer restorations were positioned on the crystallization tray, secured, and attached using an object fixed within the firing chamber **(Table 1 & 2)**. The crystallization tray was removed at the conclusion of the session to allow the occlusal veneer to cool at room temperature in an area that was dry. The subsequent stage involves glazing using the Programat EP3010 (Ivoclar Vivadent, Zürich, Switzerland) in a furnace, according to the manufacturer's guidelines.

Table 1. Amber press crystallization parameters for Programat EP 3010 ceramic furnace

Start Temp (B, C°)	Heating Rate (°C/ min)	Max Temp. (°C)	Holding Time (Min.)	Vacuum On (°C)	Vacuum Off (°C)	Low temp. (°C)
400	60	840	15:00	550	840	690

Table 2. Standard Firing for crystallization of Amber mill

Starting temperature (B, C°)	Heating rate (°C/ min)	Max. temperature (°C)	Holding in Time vacuum (Min.)	Vacuum On (°C)	Vacuum Cooling temperature (°C)
700	60	915	15/20	700	900

2.7 Bonding procedure

The intaglio surface of the restoration of both restorations with two fabrication techniques (pressing and milling) follows the same steps**.** Apply 9.5% of hydrofluoric acid (HF) etch gel to the intaglio surface of the restoration for 20 seconds. The acid gel was then removed with a copious amount of air water for 30 seconds, followed by drying. On the etched surface of the occlusal veneer, a silane coupling agent was applied with a microbrush, and it was left to dry for 60 seconds for reaction; then, dryness was done for 30 seconds. Self-adhesive dual-cure automixed resin cement (Relay X dual-cure resin cement, Germany) was used to cement the occlusal veneer restoration; it was applied on the fitting surface of the restoration. After being seated on the prepared epoxy model, the restorations were placed on a specially constructed loading apparatus and loaded with 3 kg continuously for 5 minutes (**Fig. 3)**. The excess cement was removed with the bond brush.

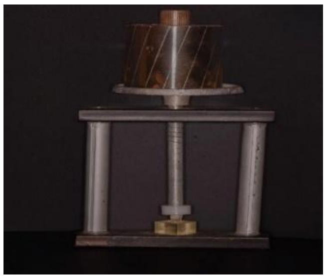

Figure 3. Restoration under constant loading during cementation

2.8 Thermocycling aging

All specimens were subjected to 10,000 cycles of temperature, simulating one year of age in a thermocycling machine (SD Mechatronik Thermocycler, Miesbacher Strabe 34, Germany). Each cycle consists of a 30-second immersion in a hot bath at 55 ± 1°C, followed by a 30-second immersion in a cold bath at 5 ± 1°C, with a 5-second break at room temperature between the hot and cold baths.

2.9 Marginal Gap Measurements

A stereomicroscope (Leica MZ 6 Stereomicroscope) at 35X magnification captures images of specimens using a built-in digital camera (Leica Microsystems CMS GmbH, Heerbrugg, Switzerland), which are subsequently downloaded to a computer using image processing software.

Specialized software (Leica StereoExplorer; Leica Microsystems) was employed to measure and evaluate the vertical gap. The apparatus was calibrated using a standard-sized object (ruler), and the measurements were provided in microns. To standardize the assessment of marginal adaptation, each surface was delineated with three points, spaced 2mm apart, on both the buccal and palatal surfaces (3 points each surface equidistance), while four points were marked on each proximal surface (4 points each surface equidistance) **(Fig. 4)**.

Figure 4. Palatal margin was scanned by stereomicroscope at magnification X35

2.10 Statistical Analysis

Statistical analysis was performed with SPSS 20®, GraphPad Prism®, and Microsoft Excel 2016. Numerical data are presented as mean and standard deviation values. All quantities data were explored for normality using Shapiro-Wilk's test and presented as minimum, maximum, median, mean, and standard deviation (SD) values. Comparison between different fabrication techniques marginal gap data was analyzed using one-way ANOVA. The comparisons of simple effects were made utilizing the pooled error term from the one ANOVA model. P-values were adjusted for multiple comparisons using the False Discovery Rate (FDR) method.

3 Results

Normality test: Exploration of the quantitative data was performed using Shapiro Wilk test and kolmogorov- Smirnov test for normality. It was revealed that the significant level (P-value) was shown to be insignificant as P-value >0.05, which indicated that data originated from the normal distribution.

<u>Marginal gap Effect of Fabrication technique:</u>

Comparisons and summary statistics of marginal gap (μm) for different fabrication techniques are presented in **Table 3** and in **(Fig. 5)**. Milled veneers (23.66±5.74) (μm) had a higher marginal gap than pressed veneers (20.40±1.94) (μm), yet the difference was not statistically significant (p=0.216).

Table 3. Comparisons of marginal gap (μm) for different fabrication techniques.

	Marginal gap (μm) (Mean±SD)		p-value
	Pressed veneers	**Milled veneers**	
Chamfer finish line design	20.40±1.94	23.66±5.74	**0.216ns**
p-value	**0.028***	**0.033***	

* Significant, ns not significant

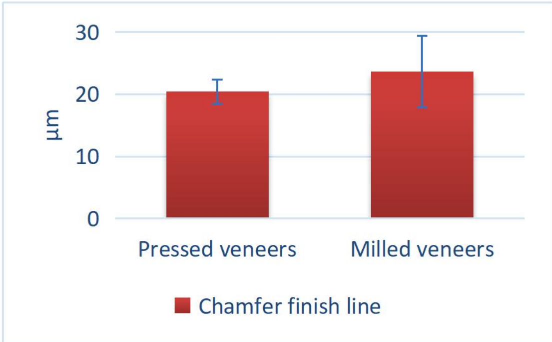

Figure 5. Bar chart showing average marginal gap (μm) for different fabrication techniques.

4 Discussion

Typodont model sample was used instead of extracted human teeth was chosen for this investigation to overcome variability caused by differences in age, anatomical features, and storage conditions, which complicate standardization. [16]

Utilizing 3D-printing technology facilitated uniformity across samples, reduced costs and preparation time, minimized material loss, and enhanced precision. [17] Additionally, computer-aided design (CAD) offered significant benefits in controlling restoration thickness and geometry, enabling standardized fabrication that diminishes clinical and laboratory inconsistencies, shortens preparation duration, accurately replicates tooth anatomy, and preserves both physical dies and digital data. [18]

Chamfer finish line occlusal veneer preparation was chosen in the current study as it has gained a conservative minimally invasive treatment in severely worn dentition cases, smooth and definable Margin, enhanced marginal fit and seal of the veneer, the rounded interior angle reduced stress distribution. The preparation, involving a 1.5mm reduction of cusps and a 1mm reduction of fossa with 1mm axial finish line for very minimal dentin exposure.[19]

Glass ceramic material, nano-lithium disilicate (Amber) was used in our investigation due to its exceptional mechanical qualities, elevated flexural strength, outstanding optical characteristics, and favorable biomechanical attributes, rendering it appropriate for posterior teeth. [12] Furthermore, consistent with prior conclusions, there is an enhancement in strength when crystal size diminishes withina specific range. [20]

The hypothesis was accepted as there was no significant difference between the two groups. The mean values of the marginal gap of the current investigation were accepted and demonstrated superior outcomes compared to other findings. This may result from the influence of Nano-lithium disilicate (Amber) with a crystal size of 0.2 μm, while Lithium disilicate exhibits a crystal size of 2 to 4 μm. [21]

The observed variation in results compared to other studies may stem from differences in crystallite size and nanostructural precision, which can influence marginal adaptation. Nano lithium disilicate materials, due to their advanced fabrication, exhibit enhanced bonding capabilities with dental tissues, resulting in superior marginal adjustment and reduced discrepancies. Their fine particle size contributes to a smoother surface, minimizing gaps between the veneer and tooth, thereby lowering microleakage risk. Additionally, the thermal and edge stability afforded by the nano-structured composition helps maintain dimensional integrity during crystallization, further supporting optimal marginal fit. [22]

The decrease marginal adaption of lithium disilicate may result from the dimensional changes occurring during the crystallization fire of CAD nano-lithium disilicate, which compromise the marginal fit of the milled restorations. [23] Occlusal veneers at a thickness of 1-1.5 mm were selected for this investigation due to the standard suggestion for the thickness of porcelain restorations. [24]

This current research study utilized epoxy resin dies due to their low modulus of elasticity, closely resembling natural dentin, and the challenges associated with standardizing natural teeth dimensions. Epoxy resin offers key advantages including durability, abrasion resistance, and precise detail replication. [25] Fabrication of occlusal veneer involved both CAD/CAM milling and pressing techniques using an identical STL file. For pressing technique, a PMMA template disc was used to improve fit and minimize marginal distortion. [26]

The restorations were milled with a five-axis milling machine, CAD/CAM technology was chosen due to its ability to control thickness and anatomy of restorations during the fabrication process. The restorations were fabricated using a five-axis milling machine, with CAD/CAM technology selected for its ability to regulate the thickness and anatomical features of the restorations through the manufacturing process. [27] A standardized cement space of 50μm was applied across methods, yielding minimal marginal gap variations and optimal marginal fit consistency. [28]

The null hypothesis of the current study was accepted as there was no significant difference between both fabrication techniques (pressing and milling), regarding marginal adaptation of occlusal veneers. The current results came in accordance with Presnell, C. [29], who examined the marginal fit of milled versus pressed lithium disilicate crowns including shoulder and chamfer margins. Also, Dolev, E., *et al.* [30], who evaluated the marginal discrepancy (MD) and absolute marginal discrepancy (AMD) of lithium disilicate crowns fabricated using pressing and CAD-CAM processes, revealing no significant difference. This also aligns with the findings of Sanches, I. B., *et al.* [31], who conducted a systematic review and meta-analysis to examine the impact of CAD-CAM and pressing techniques on the marginal adaptation of lithium disilicate restorations. In vitro studies indicated no difference in manufacturing compared to in vivo studies, and the two fabrication techniques did not influence the results regarding marginal adaptation.

The findings of the present investigation are in disagreement with Ioannidis, A., *et al.* [32], who evaluated the marginal and internal fit of ultra-thin 3D printed ZrO2 occlusal veneers in comparison to CAD/CAM-fabricated ZrO2 and heat-pressed lithium disilicate ceramic (LS2) on molars. This study determined that milling technology exhibited a reduced marginal gap and superior internal fit value in comparison to 3D printing and pressing methods. CAD/CAM occlusal veneers demonstrated superior outcomes compared to the pressing procedure due to the use of PMMA templates due to its limitation as it may influence the final restoration quality. One primary drawback lies in the mechanical properties of PMMA, particularly its susceptibility to dimensional changes during the milling and pressing phases. These alterations can compromise the accuracy of the internal fit and marginal adaptation of the definitive restoration, also PMMA, being an organic polymer, undergoes thermal decomposition when subjected to the high temperatures required during burnout. This decomposition can lead to incomplete elimination of residues within the investment mold, potentially interfering with the integrity of the ceramic material during pressing the formation of internal voids or porosities within the final ceramic restoration. These voids not only compromise the mechanical strength of the restoration but may also affect its optical properties and long-term clinical performance.

El Sayed, S. M. [33], who assessed the marginal adaptation and fracture resistance of lithium disilicate and zirconia-reinforced lithium disilicate ceramic restorations fabricated using two processing techniques, specifically CAD/CAM and pressing, following fatigue loading. Their findings indicate that the pressing process exceeds milling because of reduced porosity, enhanced flexural strength, and superior marginal fit. Machinable ceramics IPS e.max CAD exhibited statistically significant greater vertical marginal gap distances compared to IPS e.max press. They indicated that this could be attributed to the pressure applied by the milling instruments and the material's inherent resistance, potentially leading to minor fractures. This phenomenon is prevalent in brittle materials such as ceramics.

5 Conclusion

1. Marginal adaptation of all occlusal veneers with different fabrication techniques used in this study showed clinical acceptance results within clinical acceptance range < 120 µm.

2. Occlusal veneers fabricated with CAD/CAM and pressing technology showed clinically comparable vertical margin adaptation.

3. Different materials and designs are to be employed for a better profound conclusion and to be recommended in further research.

Limitations

This Research did not take into account the parameters of the oral environment, including oral fluids, pH levels, and heat fluctuations. The use of epoxy resin dies as compared to actual teeth, could not accurately replicate clinical settings. Additional examinations assessing the interior fit are required. This study used a single material, while more materials require further investigation. Chewing simulation can be used as a mechanical aging technique to replicate the real mouth environment.

Authors' Contributions

Nourhan Tarek managed the application of the materials and wrote the manuscript. Aya Ahmed supervised experimental work, methodology, Ahmed Hamdy managed the conceptualization, supervised the experimental work, methodology, recourses and reviewed the manuscript.

Conflict of interest

The authors declare that they hold no competing interests.

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