ASSESSMENT OF MARGINAL ADAPTATION OF CAD CAM ALL CERAMIC CROWNS WITH TWO DIFFERENT MARGIN DESIGNS

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Abstract

Aim: This study examined the effect of cervical finish line preparation on the marginal gap of all-ceramic crowns produced, using CAD CAM technology and two developed materials: IPs Emax and Zirconia-reinforced lithium silicate (Celtra Duo).

Methods: Two full human premolars were constructed with similar preparation dimensions, except for a (1.00 mm) on the margin. For sample standardization, 40 epoxy replicas of prepared premolar teeth were produced. Deep chamfer (DC group, n = 20) and knife-edge (KE group, n = 20) finish lines were used to split samples. Each group was divided into two ten-samples subgroups by building material. Subgroup 1: lithium di silicate ceramic (n=10) and Subgroup 2: lithium silicate reinforced with zirconia (n=10). All crowns were CAD/CAM-made. All samples were aged by thermo-cycling after being bonded to a tooth, and the marginal gap was measured using a stereomicroscope.

Results: The findings demonstrated an increase in the marginal gap between vertical preparation (243.938) and deep chamfer, regardless of the material (202.913.6). In addition, regardless of methodology, the difference between E-max (244.337.9) and Celtra (202.512.) expanded considerably.

Conclusions: Vertical preparation was an alternative to horizontal preparation for finish lines. Furthermore, sound tooth structure should be kept throughout the fabrication of fixed abutments in order to give a less intrusive option to the horizontal finish line, as the difference was not statistically significant.

Key words: Vertical preparation, CAD/CAM technology, Zirconia reinforced lithium silicate (Celtra Duo), Epoxy.

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Introduction

There are essentially two types of tooth preparations for fixed prosthetic restorations: preparation with a predetermined margin, often called horizontal preparation, and vertical preparation with an indefinite margin.

In horizontal preparations, the edge leaves a clear line on the teeth, which is mirrored in the imprint and on the working model, but no such line is left in vertical preparations. This is likely why prosthodontists favors horizontal preparations. For vertical preparations, the margin is positioned according to gingival tissue data; nevertheless, the lack of a well-defined line makes it difficult to achieve an aesthetically attractive outcome, and there is a danger of metallic margin deformation during porcelain burning and functional stress. Some papers have suggested that this product may cause gingival recession and discomfort. [(1)]

With the rise of computer-aided design/computer-aided manufacturing (CAD/CAM) and increasing number of machinable attractive materials have been developed, natural aesthetic appearance and durability are essential goals when fixing teeth with single crowns and fixed partial dentures.

In the 1980s, dentistry incorporated CAD/CAM (computer-aided design/computer-aided manufacturing) technology. In 2005, IPS e.max® CAD (Ivoclar Vivadent, Schaan, Liechtenstein) was introduced as a breakthrough in milling procedures for lithium disilicate glass ceramic.

It is essential to achieve close marginal adaptation for the long-term clinical success of single unit or fixed partial dentures (FPD) and for the prognosis of the replaced tooth. The solubility of the luting agent can result in the formation of a space between the tooth and the restorative material, leading to microleakage, plaque accumulation, caries, and ultimately the restoration's failure.

The hypothesis of this study is that substantial differences will exist between the various finish line groups.

MATERIALS & METHODS

Two removed premolar teeth were retrieved from the maxillofacial surgery clinic of the Faculty of Dentistry at Minia University for objectives including diabetes, loose teeth, orthodontics, and periodontal disease. After informing patients, their agreement will be obtained prior to utilizing their teeth in a scientific investigation. A tooth sample was utilized to generate a silicon index, which was then employed to assure equitable tooth reduction.

The dimensions of the preparations were identical with the exception of the crown margin, where one group had a 1.00 mm deep chamfer and the other group had a knife-edge. A 2.0 mm occlusal reduction, a 1.2–1.5 mm axial reduction, a total convergence angle of 6 degrees, and rounded line angles.

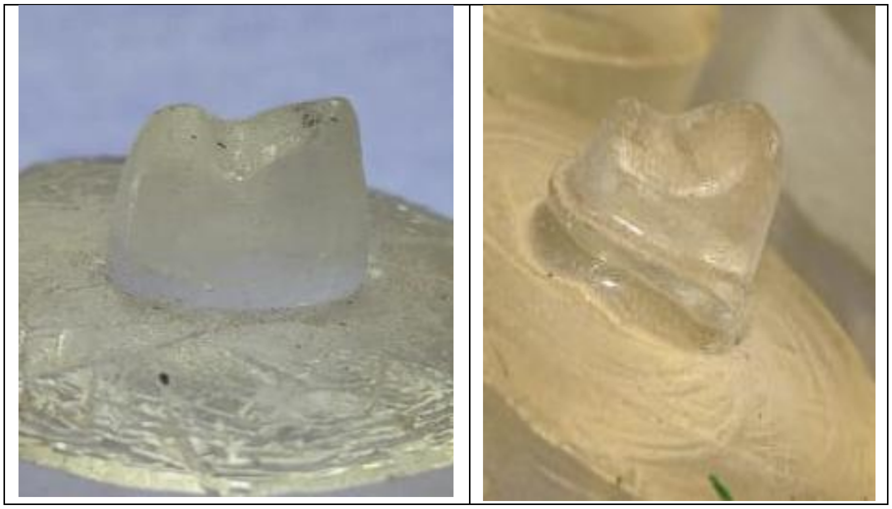
a. **Deep chamfer tooth preparation.**

The tooth was prepared according to the guidelines for preparing all ceramic crown restorations. The prepared teeth met the following specifications: a 1mm deep chamfer finish line, a 0.5mm occlusal to cementoenamel junction, a 5mm occluso-axial height, a 2mm occlusal reduction, and 6-degree axial wall conversions. Each was prepared by tapered rounded end stone (Medit, I750, Korea). The occlusal preparation was carried out in accordance with the anatomical contour.

b. **Vertical tooth preparation.**

Using diamond drills, the following vertical tooth preparation procedures were carried out (Sweden & Martina S.p.A., Via Veneto 10, 35020 Due Carrare (PD), Italy). The mesiodistal zone prepared with a coarse-grit thin flame drill (FG862/020C). In order to prepare the occlusal surface, the tapered drill (FG856/018) was aligned with the cusp angle. From the tip of the cusp to the enamel-dentin border, a 45° vestibular and lingual preparation was produced. With the coarse-grit drill, the vestibular and palatal supragingival axial reduction was completed. After reducing the circumference of the teeth, go to the subsequent procedure,progressively verticalize the drill to line the vestibular preparation with the axial walls. Red-ringed drills (fine) and, if necessary, yellow-ringed drills (coarse) were utilized to finish tooth preparation (super fine). In the cervical region where the crown margin will be positioned, the surface was polished.

Samples of epoxy were created in an effort to address problems encountered during tooth preparation, including as fractures and enamel hypomineralization. Figure (1) (a, b)



(a) **(b)**

Figure (2) (a, b): Resin - Epoxy Samples.

Based on the kind of cervical finish line preparation, all samples were separated into two groups: deep chamfer (DC group, n = 20) and knife-edge (KE group, n = 20). Each group will then split into two subgroups (ten for each). Sub group1: lithium di silicate ceramic (n =10), and Subgroup 2: lithium silicate reinforced with zirconia (n=10).

Twenty samples with a deep chamfer and twenty with a knife edge design (n= ten lithium disilicate and n= ten zirconia-reinforced lithium silicate for each) were created using prefabricated ceramic blocks and copy-milling technology.

For cementation of both groups, dual-cure self-adhesive resin cement (G-CEM capsule, GC Co., Japan) was applied using an auto mixing gun to the fitting surface of restorations. The cement-retained crowns were subjected to thermocycling (Robota automated thermal cycle; BILGE, Turkey) with water serving as the transfer medium and cyclic loading (Figure 2, a, b).

(a) (b)

Figure (2) (a, b): Processed Crowns after Cementation

Methods of thermal cycling followed by cyclic loading (using the ROBOTA chewing simulator (Model ACH-09075DC-T, LTGERMANY), which might offer cyclic loading. The force exerted was 5 kg, which is equivalent to a chewing force of 49 Newtons. To imitate the clinical situation of six-month chewing, the test was repeated 75,000 times.

To examine the margins, all samples were sectioned and seen at a variety of magnifications and stereomicroscopes. Determine the accuracy of the marginal gap as the greatest distance between the tooth preparation's line and the crown's margin.

For comparisons between classes, a one-way analysis of variance (ANOVA) was conducted, whereas a two-way analysis of variance (ANOVA) was used for comparisons among subgroups. Two related sample groups were compared using a paired sample t-test. Using a t-test for independent samples, samples from two unrelated groups were compared.

Results

This study evaluates the marginal gap of all ceramic CAD/CAM crown restorations in relation to the effect of cervical finish line preparation and various manufactured materials.

Marginal gap assessment:

I. Determining the marginal gap between different techniques regardless the material.

Regardless of the material, a comparison of the marginal gap between different procedures revealed a substantial increase in the marginal gap between vertical preparation (243.938) and deep chamfer (202.913.6) (p = 0.005). Table (1), Figure (3)

Table (1): Comparison of marginal gap between different techniques regardless the material.

		Deep chamfer	**Vertical preparation**	**P value**
		N=10	**N=10**	
Marginal gap (µm)	*Range* *Mean ± SD*	(181.8-232.3) 202.9±13.6	(197.2-294.7) 243.9±38	***0.005****

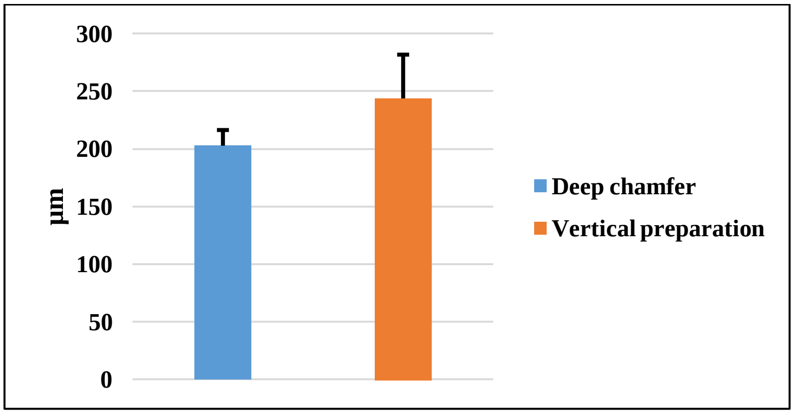


Figure (3): Bar chart representing comparison of marginal gap between different techniques regardless the material.

II. Determining the marginal gap between different materials regardless the technique.

Comparison of marginal gap between different material regardless the technique showed significant increase of marginal gap in E-max (244.3±37.9) compared with Celtra (202.5±12.7), p value = 0.004. **Table (2), Figure (4)**

Table (2): Comparison of marginal gap between different materials regardless the technique.

		Celtra N=10	E-max N=10	P value
Marginal gap (µm)	*Range* *Mean ± SD*	(181.8-226.4) 202.5±12.7	(195.7-294.7) 244.3±37.9	***0.004****

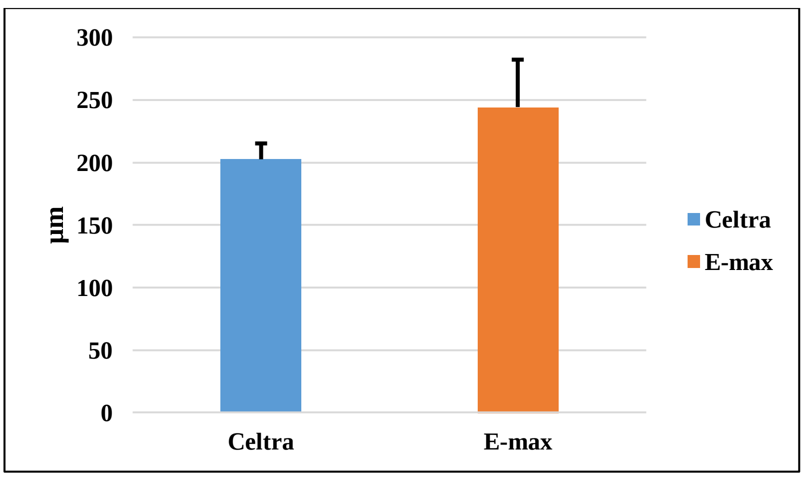


Figure (4): Bar chart representing comparison of marginal gap between different materials regardless the technique.

III. Determining the marginal gap between different techniques using celtra material.

Comparison of marginal gap between different techniques using Celtra showed insignificant differences as it was in vertical preparation (209.8±12) and in deep chamfer (195.3±9.5), p value = 0.068. **Table (3), Figure (5)**

Table (3): Comparison of marginal gap between different techniques using celtra material.

Celtra		**Deep chamfer**	**Vertical preparation**	**P value**
		N=5	**N=5**	
Marginal gap (µm)	*Range* *Mean ± SD*	(181.8-207.3) 195.3±9.5	(197.2-226.4) 209.8±12	*0.068*

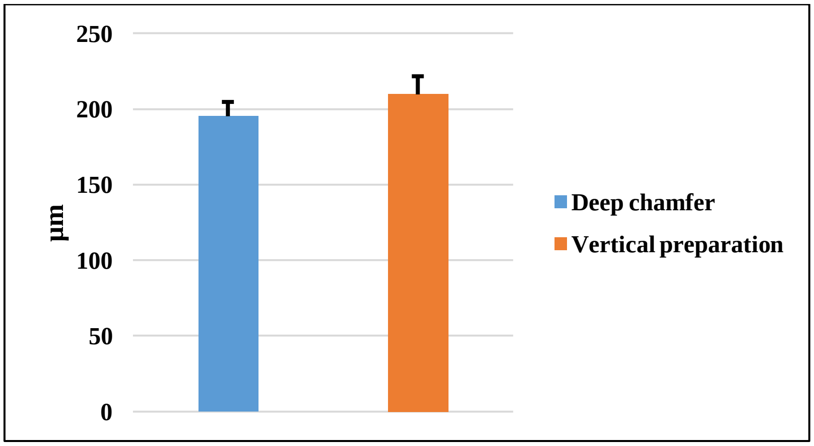


Figure (5): Bar chart representing comparison of marginal gap between different techniques using celtra material.

IV. Determining the marginal gap between different techniques using E-max material.

Comparison of marginal gap between different techniques using E-max showed significant increase of marginal gap in vertical preparation (278.1±13.8) compared with deep chamfer (210.5±13.6), p value < 0.001. **Table (4), Figure (6)**

Table (4): Comparison of marginal gap between different techniques using E-max material.

E-max		**Deep chamfer**	**Vertical preparation**	**P value**
		N=5	**N=5**	
Marginal gap (µm)	*Range* *Mean ± SD*	(195.7-232.3) 210.5±13.6	(256.2-294.7) 278.1±13.8	***<0.001****

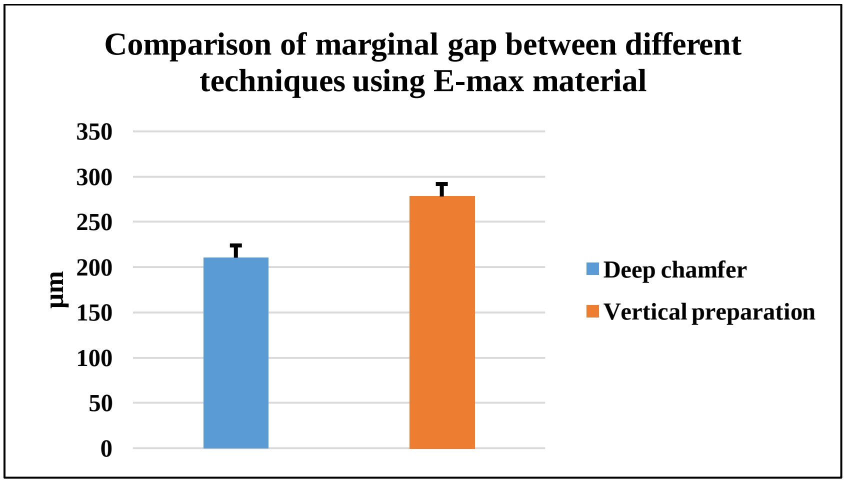


Figure (6): Bar chart representing comparison of marginal gap between different techniques using E-max material.

V. Determining the marginal gap between different materials using deep chamfer technique.

Comparison of marginal gap between different material using deep chamfer technique showed insignificant difference as it was in E-max (210.5±13.6) and in Celtra (195.3±9.5), p value = 0.075. **Table (5), Figure (7)**

Table (5): Comparison of marginal gap between different materials using deep chamfer technique.

Deep chamfer		Celtra	E-max	P value
		N=5	**N=5**	
Marginal gap (μm)	*Range* *Mean ± SD*	(181.8-207.3) 195.3±9.5	(195.7-232.3) 210.5±13.6	*0.075*

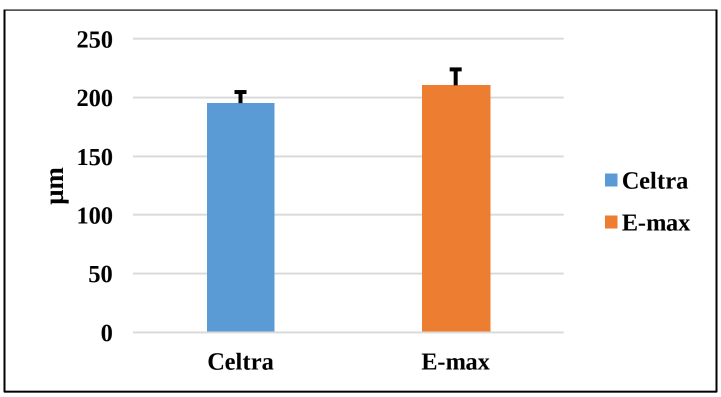


Figure (7): Bar chart representing comparison of marginal gap between different materials using deep chamfer technique.

VI. Determining the marginal gap between different materials using vertical preparation technique.

Comparison of marginal gap between different material using vertical preparation technique showed significant increase of marginal gap in E-max (278.1±13.8) compared with Celtra (209.8±12), p value < 0.001. **Table (6), Figure (8)**

Table (6): Comparison of marginal gap between different materials using vertical preparation technique.

Vertical preparation		**Celtra**	**E-max**	**P value**
		N=5	**N=5**	
Marginal gap (µm)	*Range* *Mean ± SD*	(197.2-226.4) 209.8±12	(256.2-294.7) 278.1±13.8	***<0.001****

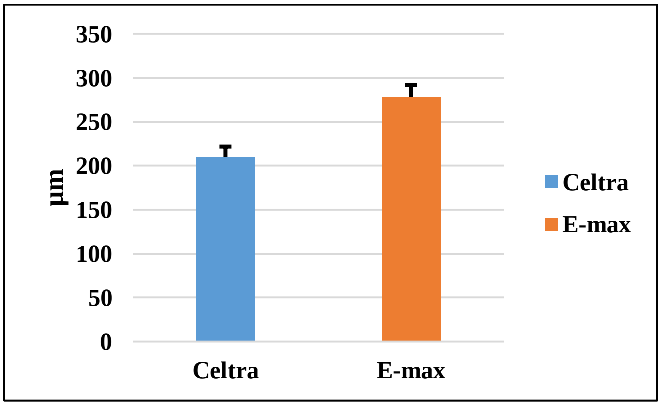


Figure (8): Bar chart representing comparison of marginal gap between different materials using vertical preparation technique.

Discussion

While generating outstanding outcomes, conservative dentistry must respect the linked biological structures to the greatest extent feasible [(2)]. The notion of minimally invasive dental restorations is crucial for the efficacy of dental restorations. Thus, minimally thick all-ceramic restorations have been commonly advocated. [(3)] Technology has contributed significantly to this conservative approach of dentistry [(4)]. Crown margins are critical in influencing the stability of restorations and related supporting tissues throughout time. Consideration must be given to the design and creation of appropriate finishing lines based on the restorative material being used, the desired aesthetic result, occlusal considerations, and the condition of the underlying tooth structure; thus, adequate planning increases the likelihood of a successful outcome. [(5)] The link between the level of the margin and the gingiva may be the most crucial biological component in preserving the long-term health of neighbouring soft tissues. Featheredge preparations enhance the BOPT approach, which provides an innovative concept based on the discovery that the gingival profile. [(6)] [(7)] The type of finish line and the selected material have the most impact on the marginal adaption of permanent prosthodontics. This study by Halawani et al. (2017) demonstrates that a strong marginal fit is one of the most crucial technical aspects for the long-term effectiveness of any restoration [(8)].

This study aims to determine the influence of cervical finish line preparation on the marginal gap of all ceramic crowns fabricated with CAD/CAM technology (in vitro study).

Numerous research with differing outcomes has explored the influence of finish-line design on the marginal and internal adaptations of ceramic crowns and diverse results present with chamfer and shoulder finish lines. [9] [10] [11] The vertical preparation technique preserves healthy dental structure while preparing teeth for permanent abutments, giving it a less intrusive alternative to the horizontal finish line. This expands the criteria to include additional clinical conditions, such as endodontically treated teeth, substantial teeth in young patients, and gingival third teeth problems. [12] [13] The vertical preparation was chosen to see if zirconia and zirconia-reinforced lithium silicate ceramics might be utilized to create aesthetically pleasing crowns with little stress retention. However, as a result of the excellent occlusal convergence of the axial walls and the geometry of the vertical margins, the quantity of exposed cement was exceedingly restricted; hence, the likelihood of plaque accumulation and cement dissolving in vertical preparation designs is minimal. [14] Chamfer finish lines are more conservative than other finish line preparations (shoulders) and less prone to undercuts. If chamfers are to be utilized with a porcelain margin, they must be sufficiently deep to guarantee that the porcelain margin is thick enough to avoid shattering. Regardless of the selected design, it is vital to properly complete the preparation to enable the smoothest possible transition between the tooth and the restoration. For this purpose, hand tools, end-cutting burs, and rubber points have all been employed.

Consequently, the maxillary premolar tooth used in this study mimics the mesiodistal and buccolingual dimensions of real teeth. In addition, the tooth was prepared in line with Ahlers et al (2007) recommendations for all-ceramic restorations. [15] Compared to horizontal preparations, the coronal seal on feather-edge preparations is clearly superior. Numerous writers have shown that vertical geometry reduces the distance between the teeth and the crown. It improves the fit, reduces cement exposure, and reduces bacterial penetration. [16] [17] Preparation and restoration design might influence the marginal adaption of the ceramic material used to restore missing tooth structure, which is of highest relevance for the scientific evidence of clinical circumstances. [18] In general, the marginal gap is deemed acceptable if it falls below 120 micrometres. [19]

Shoulder margin design was superior to feather-edge margin design in terms of fracture strength, whereas monolithic conventional zirconia was superior than monolithic transparent zirconia. [20] CAD/CAM technology facilitates the production of standardised samples using processes that offer several benefits over human production. The most important quality is its faultless duplicability. The process is cost-effective since it does not require noble metal alloys or other expensive materials. [21] [22]

Recent CAD/CAM technology has enabled the creation of a variety of treatment protocols utilizing sophisticated dental ceramics. The CAD/CAM technology produces milled restorations with a more uniform structure, increased accuracy, and improved time efficiency. In addition to adequate tooth-to-ceramic adhesion and enhanced mechanical qualities, lithium disilicate ceramics have been developed to offer the appropriate aesthetic effects, especially in indirect dental restorations.

The prepared tooth was scanned using a high-precision extra-oral scanner (Medit i710) with a 2-micron scan accuracy, and all samples were sprayed with optical spray (Renfert oclutec spray) to generate a consistently reflecting surface, hence boosting the scan accuracy.

Restorations were created by increasing the minimal thickness of restorations by 2 mm at the occlusal surface in order to provide restorations with the correct proportions that resemble genuine premolar teeth. It was determined that cement spacing settings had a statistically significant effect on the marginal fit and internal adaptability of CAD-CAM restorations; thus, the cement spacing was altered to 60 microns. The milling was performed using a chairside Sirona MCXL milling machine with an accuracy of up to 5 microns. MCXL-EF is competitive and may allow for chairside manufacture with exceptional milling outcomes. In addition, it was determined that 5-axis milling provides more accuracy; nevertheless, the 4-axis CEREC MCXL extra-fine mode produced chairside milling results comparable to those of 5-axis milling systems with a shorter milling time.

Methods of thermal cycling followed by cyclic loading (using the ROBOTA chewing simulator (Model ACH-09075DC-T, LTGERMANY), which might offer cyclic loading. The force exerted was 5 kg, which is equivalent to a chewing force of 49 Newtons. To imitate the clinical situation of six-month chewing, the test was repeated 75,000 times. In the current scientific literature, mechanical testing parameters and cyclic loading procedures vary significantly. One million loading cycles is comparable to five years of clinical care. [23]

Dual cure self-adhesive resin cement was used for cementation, which provides a straightforward bonding technique and saves time compared to the application of multi-step adhesives. In addition, several writers claim that self-adhesive resin cement has attained micro-leakage values and marginal adaptation equivalent to adhesive resin cement. Dual adhesive self-treatment resin cement was used without the multiple stages required by typical adhesives, enabling a simple and rapid bonding process. [24] [25]

This sample was examined with a stereomicroscope at a magnification of 30x (a Ma 100 Nikon stereomicroscope from Japan). Using software, the recordings were created and processed (Omnimet image analysis software). As the gold standard, stereomicroscopy measurements of 30 microns or fewer were utilized to evaluate the relevance of various designs on marginal adaption. As part of a larger investigation, several sample characteristics were analysed. As said by Rastogi A. and Kamble V., 2011 the marginal leakage analysis disproved the hypothesis that there would be a substantial difference between the various finish line groups. [26]

Even while the practical feather-edge kind of finish line is not suggested, particularly for all-ceramic structures, it was fascinating to see that the ceramic thickness at the edges had no influence on this paper findings. Given that the marginal difference in the chamfer finish line design was shown to be smaller, [27] [28] it was decided that full coverage restorations with subgingival finish lines have a detrimental impact on periodontal health, [29] that demonstrated a deterioration in clinical periodontal markers one to three years following restoration installation. Previous research has reported on this topic [30] [31] [32] [33]

Conclusions:

Within the constraints of this study, the following results were discovered:

1. The vertical alignment of finish lines offered an alternative to the horizontal alignment.
2. The preparation of teeth vertically for permanent abutments maintains healthy tooth structure, making it a less intrusive alternative to the horizontal finish line.
3. Observed significantly separation between E-max (244.337.9) and Celtra Due (202.512.5).

Recommendations:

For this approach to be scientifically validated, more clinical and biological study is necessary. In addition to in vitro and in vivo studies to evaluate the clinical performance (Marginal Adaptation) of newly developed CAD/CAM materials such as Celtra Duo produced using CEREC technology, a prospective study will be conducted to determine if clinicians can use the vertical tooth preparation procedure with predictable results.

List of Abbreviations:

CAD- CAM: computer aided design computer aided manufacturing, KE: knife edge, DC: deep chamfer, FPD: fixed-partial-dentures, ZLS: zirconia-reinforced lithium silicate

Declarations:

- Ethics approval and consent to participate

Not applicable

- Consent for publication

Not applicable

- Availability of data and materials

The authors announce that the data supporting the results of this study are existing within the article.

- Competing interests

No competing interests.

- Funding

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