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The Effect of Various Placement Techniques on the Microhardness of Class II (Slot) Resin Composite Restorations

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Abstract

Aim: To analyze the influence of various placement techniques on Vickers microhardness of Class II cavities restored using resin composite in different depths and layers.

Methods and Materials: Sixty-four standardized Class II cavities ($5.0 \times 3.0 \times 1.5$ mm^3) were prepared in sound human, maxillary premolars. The cavities were divided into four experimental groups (n=16) according to the composite placement technique used: incremental technique using a Palodent matrix (IP), incremental technique using a transparent matrix (IT), centripetal technique using a Palodent matrix (CP), and the centripetal technique using a transparent matrix (CT). The cavities were restored with Single Bond, Z100 composite resin system. After 24 hours of storage in envelopes in an amber-colored box, the restorations were finished, polished, and kept for one week before conducting a hardness test. The microhardness test was carried out using a 0.5 kg load for 20 seconds at different depths and layers of proximal surfaces. Statistical analysis was done using a t-test, ANOVA, and a Tukey's test (α=0.05).

Results: In contrast, the matrix bands, the methods of composite insertion, had a significant effect on hardness. The greatest surface hardness of resin composite was related to the use of the centripetal technique and a transparent matrix ($p<0.05$). With regard to cavity depths, the hardness at the top surface was significantly greater, followed by the middle and bottom cavity depths. A greater hardness was obtained in the mesial-distal direction within the external layer compared with the middle and internal layers using the centripetal method ($p<0.05$).

Conclusion: The kind of matrix and filling technique could have a significant effect on surface microhardness. The top surface had the greatest hardness in comparison to different depths. In the centripetal technique, the external layer of the proximal wall had greater hardness than the other layers.

Clinical Significance: While the microhardness of all of the experimental placement techniques in the different depths and layers was within a

clinically acceptable range, the greatest hardness was obtained using the centripetal technique with a transparent matrix, making it the technique of choice.

Keywords: Matrix bands, microhardness, resin composite, insertion techniques.

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Introduction

Although composite resin restorations have been placed in posterior teeth since the 1970s, their clinical performance has remained questionable. The most commonly cited reasons for the failure of posterior composites in clinical studies are secondary caries, fracture, marginal deficiencies, and wear.[1] One of the main disadvantages of resin composites has been inadequate resistance to wear due to incomplete polymerization.[2] The effectiveness of polymerization of the composite resin decreases with an increase in curing depth regardless of exposure time.[3] Various materials (e.g., light curing tips, matrix systems, reflecting wedges, etc.) have been developed and several techniques (e.g., multilayer insertion techniques, in contrast to bulk packing methods) have been introduced to improve the characteristics of light-cured composites in an attempt to overcome this limitation.[4]

Use of various matrix systems has had no influence on the clinical performance of Class II resin composites.[5] Kays et al. believed, "A stainless steel matrix resulted in the least amount of change in hardness measured from the gingival to the occlusal surfaces. Clear plastic matrix bands with the material cured from the occlusal surface had minimal hardness at the gingival surface, but substantially greater hardness at the occlusal surface."[6] No statistically significant difference in microhardness was found at any depth of composite restorations when either the bulk or incremental insertion techniques were used.[7] Szep et al.[4] suggested, "The highest surface hardness of composite resin was related to transparent matrices. In deep cavities when a metal matrix system is used in combination with the centripetal technique, a significant decrease in microhardness values was noted."[4]

The degree of polymerization can be measured using infrared spectroscopy and electron resonance. These measurement methods can directly quantify the percentage of double carbon links converted into simple links during polymerization reactions. However, these methods are complex, time-consuming, and very expensive. Hence, the use of hardness tests has become very popular due to their relatively simple technique and the reliability of their results.[8]

The present study was conducted because there are only a few studies that compare the role of matrix bands in combination composite insertion techniques with microhardness as a dependent variable. The null hypotheses of this study were:

1. No significant difference was found with either the matrix bands or the different insertion techniques alone.
2. No significant difference was gained in the overall mean microhardness of the experimental groups.
3. No significant difference was achieved among the test groups in either the occlusal-gingival or mesial-distal direction.

Methods and Materials

General Study Design

Sixty-four intact human maxillary premolars freshly extracted for orthodontic purposes were selected for this *in vitro* study. Next, the teeth were thoroughly scaled using curettes to remove calculus and remaining tissue tags, then polished with a slurry of pumice and water using a conventional speed handpiece. Each tooth was individually invested in clear auto polymerizing resin (Orthodontic resin, DENTSPLY Caulk Co., Milford, DE, USA) on one proximal surface and ground in a buccal to lingual direction on the other proximal surface using a diamond saw mounted on a low-speed handpiece (KG Sorensen Ind. Com. Ltda., Barueri, SP, Brazil) to create a parallel plane area at the opposing proximal surfaces (mesial against distal). These flattened proximal surfaces were necessary to facilitate Vickers hardness testing after placement of the composite resin restorations.

Vertical slot-type Class II cavities were then prepared on the mesial or distal surfaces of each tooth with parallel buccal and lingual walls using a #245 tungsten carbide bur (SS White, Great White Series, Lakewood, NJ, USA) in a high-speed handpiece (Kavo do Brasil AS, Joinville, SC 89221-040, Brazil) with water coolant. After five preparations, a new bur was used.

A periodontal probe was used as a guide to create a standard-sized preparation. The occlusal-gingival length and the mesial-distal depth were measured to be 5.0 mm and 1.5 mm respectively. The buccolingual extensions were estimated to be 3.0 mm. No bevels were used in the cavity preparations. One operator prepared all cavity preparations, while another investigator checked the cavities prior to restoration to ensure they conformed to the required dimensions.

The cavity preparations were randomly divided into four groups respectively: first, the samples were divided into two groups based on the type of matrix used (transparent or Palodent); then each group was categorized into two subgroups according to the type of insertion method for the composite resin (incremental or centripetal). A strip of the precontoured transparent #773 matrix band (Hawe Neos, Bioggio, Switzerland) (T), or sectional metal matrix band (Palodent® Sectional Matrix System (DENTSPLY Caulk, Milford, DE, USA) (P) was glued (UHU Hotglue, Buhl, Germany) to the resin block in which each tooth was mounted before preparation, without forming marginal gaps between the cavity and the matrix band.

The teeth were restored using Single Bond (3M ESPE, St. Paul, MN, USA), a total-etch, single-bottle adhesive, and Z100 (3M ESPE, St. Paul, MN, USA), A2 shade, a hybrid resin composite, according to the manufacturers' instructions using the following placement techniques:

- **Incremental technique (I)**: The first layer of resin composite (thickness = 0.5 mm) was placed on the gingival floor; then the second, third, and fourth layers (thickness = 1.5 mm) were placed horizontally to complete the filling.
- **Centripetal technique (C)**: The first increment of resin composite was applied on the gingival wall of the proximal box, packed cervically near the axial wall causing the resin to climb upward in contact with the inner surface of the matrix band. This increment of the restoration was sculpted and light-cured and the metallic matrix band removed. Subsequent increments (1.5 mm) were applied horizontally toward the occlusal surface of the cavity. The same thickness and number of increments and light irradiation times were used for the two buildup techniques.

Each increment of composite was cured for 40 seconds using an Optilux 500 curing unit (Demetron-Kerr, Orange, CA, USA) at 600mW/cm^2. All curing procedures were performed at the occlusal surface of the cavity and no post-curing technique was used. The four resulting experimental groups (n=16) included incremental and Palodent matrix (IP), incremental and transparent matrix (IT), centripetal and Palodent matrix (CP), and centripetal and transparent matrix (CT).

Microhardness Test

After 24 hours of storage in distilled water at 37°C, finishing and polishing procedures were carried out using a surgical blade and Sof-Lex disc (3M ESPE, St. Paul, MN, USA). The samples were stored in envelopes in an amber-colored box with 100% humidity at 37°C for one week before the hardness test and then thermocycled 1000 cycles at 5°C and 55°C, with a one-minute dwell time in distilled water and a five-second transfer time. The Vickers Diamond Pyramid Hardness Number (μVDH) of the planed proximal resin composite surfaces was measured with a microhardness meter (Ernest Leitz, Wetzlar, Germany, n. 479919) with a load of 0.5 kg for 20 seconds. Indentations were placed at 200, 2500, and 4800 μm from the gingival margin, and at 200, 1500, and 2800 μm from the lingual wall (Figure 1).

The number of μVDH is the applied load (kgf) divided by the surface area of the indentation (mm^2).

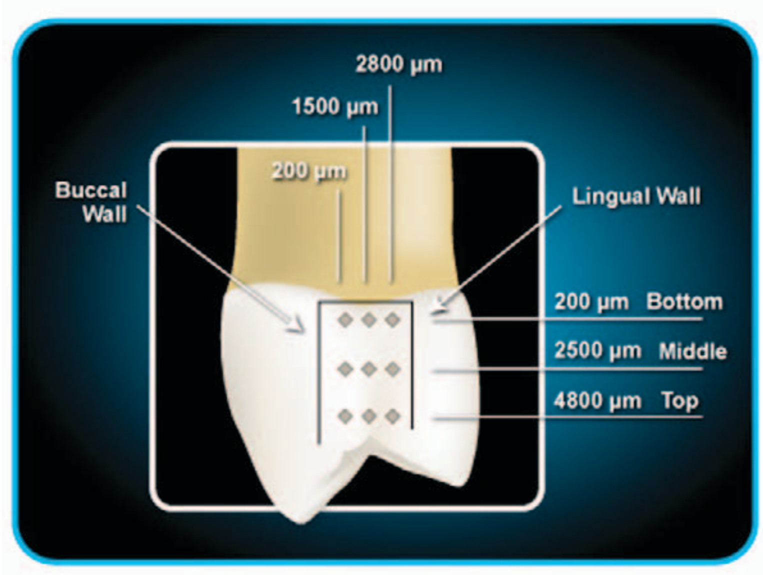

Figure 1. Diagram of Vickers indentation location in the proximal surface in the occlusal-gingival direction.

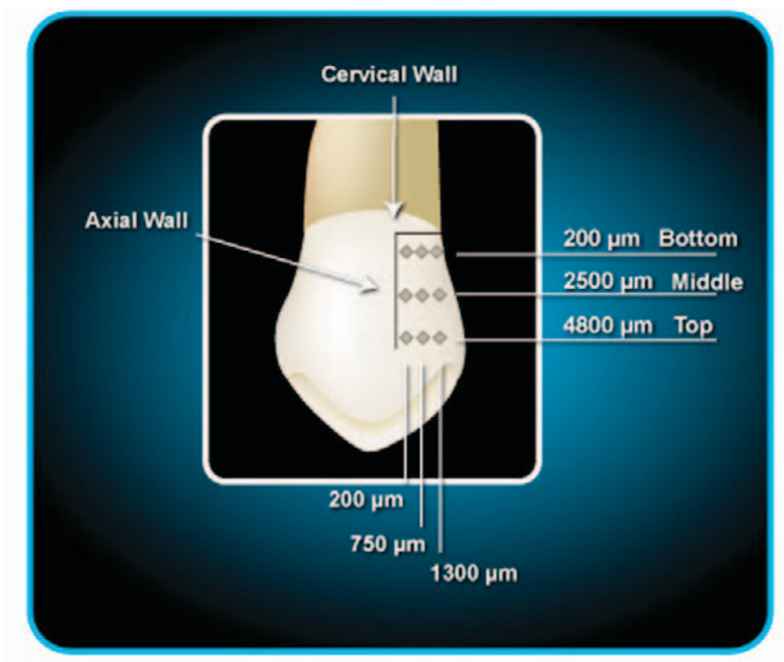

Figure 2. Diagram of Vickers indentation location in the internal (200 µm), middle (750 µm), and external (1300 µm) layers in the mesial-distal direction.

$$VDH = \frac{2F\sin\left(\frac{136^\circ}{2}\right)}{d^2}$$

where:
F= Load in kgf, **d**= Arithmetic mean of the two diagonals, **136**°=Angle between opposite faces of the diamond, **VDH**= Vickers Diamond Hardness

Then samples were sectioned longitudinally in a mesial-distal direction. One section of each specimen was polished with 320-, 400-, 600-, and 1000-grit sandpapers, then polished with white felt discs using alumina-Al_2O_3- suspension and diamond paste with granulations of 6, 3, and 1 µm (DP-Paste M, Struers FF, Ballerupm, Denmark) in preparation for the Vickers hardness measurements. Then indentations were placed at

200, 2500, and 4800 µm from the gingival margin and at 200, 750, and 1300 µm from the axial wall (Figure 2) using the microhardness meter.

Composite microhardness varies in different areas of the same restoration, and any single measurement for microhardness of any sample cannot precisely reflect the composite microhardness of that restoration. Therefore, the microhardness means of each depth and layer for experimental groups were calculated and subjected to a T-test, an ANOVA, and a Tukey's test to compare the µVDH at the 95% confidence level.

Results

The T-test showed the centripetal method of composite placement had significantly higher microhardness than the incremental technique ($p<0.05$), but the type of matrix band had no significant effect on µVDH ($p>0.05$).

Due to the presence of interaction, the one-way ANOVA revealed a statistically significant difference among the four experimental groups ($p<0.05$). The post hoc test (Tukey HSD) demonstrated significant differences between the CT (102.12±2.4) and IP (94.57±7.33) groups (Figure 3).

The mean values and standard deviations of microhardness in the proximal box of experimental groups in the occlusal-gingival and mesial-distal longitudinal sections are shown in Tables 1 and 2.

A comparison of the different depths and layers the ANOVA indicated the incremental method with Palodent matrix (IP) demonstrated the

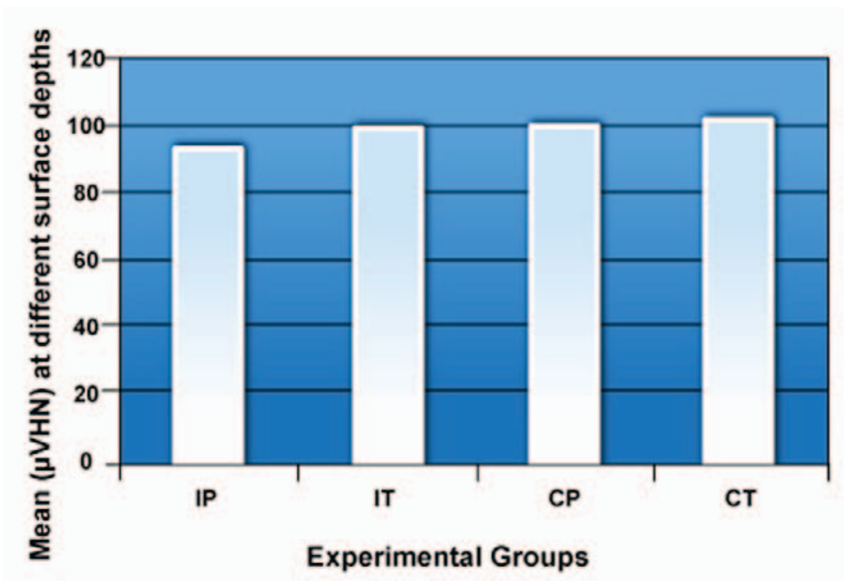

Figure 3. Overall mean microhardness of each experimental group.

Table 1. Means and standard deviations of surface micro Vickers hardness number (µVDH) for various placement techniques and depth of polymerization.

Group	Insertion Method	Matrix Band	Depth (occlusal-gingival direction)					
			Bottom (200 µm)		Middle (2500 µm)		Top (4800 µm)	
			Mean	SD	Mean	SD	Mean	SD
IP	Incremental	Palodent	92.44	10.07	96.71	7.47	102.57	3.04
IT	Incremental	Transparent	95.20	8.80	100.07	6.50	107.64	10.31
CP	Centripetal	Palodent	92.34	14.41	97.04	11.71	107.20	18.25
CT	Centripetal	Transparent	92.34	13.05	102.36	10.07	112.40	6.49

Table 2. Means and standard deviations of micro Vickers hardness number (µVDH) for various placement techniques and multiple layers of the proximal box.

Group	Insertion Method	Matrix Band	Layers (mesial-distal direction)					
			Internal (200 µm)		Middle (750 µm)		External (1300 µm)	
			Mean	SD	Mean	SD	Mean	SD
IP	Incremental	Palodent	95.04	11.47	93.71	7.70	94.57	8.04
IT	Incremental	Transparent	96.20	1.10	97.17	6.10	96.64	13.01
CP	Centripetal	Palodent	95.87	10.47	94.24	14.71	107.40	10.25
CT	Centripetal	Transparent	94.61	18.05	98.36	12.07	110.25	7.40

least microhardness, but the centripetal method using a transparent matrix (CT) significantly presented the highest value of microhardness ($p<0.05$). Microhardness of the upper surface was significantly higher than the middle and bottom surfaces in the four experimental groups ($p<0.05$). The external layer in the mesial-distal direction had a higher hardness than the other layers in the centripetal method of filling ($p<0.05$), while the centripetal technique with Palodent or transparent matrices had the greatest hardness in its external layer (CP=107.40±10.25, CT=110.40±7.40 µVDH).

Discussion

An indirect method for evaluating the relative degree of conversion of composite resins was used in this study to measure the microhardness of Class II composite restorations at various depths and layers after placement when four insertion techniques were used. Unlike other studies,[9,10,11,12] this investigation was done on natural human teeth. Therefore, gamma irradiation could be used to sterilize the teeth, as it both is effective and has no adverse effects on the structure and morphology of enamel and dentin surfaces.[13]

The optimization of the properties of composite restorations might be related to factors such as the type of polymerization, kind and shade of composite materials, cavity shape, light-curing procedure, and placement technique.[14]

Microhardness was evaluated to assess the following:

- The degree of polymerization and consequently the mechanical success of the restoration[4,15,16]
- Wear resistance of the restoration
- Ability to maintain a stable form[10] to ensure optimum physical-mechanical properties
- Prevention of cytotoxicity of inadequately polymerized composite resin material.[17]

Microhardness was tested using a Vickers indenter, since it is more suitable (compared with a Knoop indenter) for comparing variations in the mechanical properties of an anisotropic material such as resin composite.[18] Higher microhardness values were obtained in the current investigation than in previous studies.[4,9] This might be due to the following:

- The 1.5 mm increments used to place the composite resin in this study
- The use of extracted teeth for cavity preparations rather than using other synthetic material (metal blocks)[6,9]
- The type and positioning of the light-curing unit
- The week-long storage of the specimens
- Employment of 1000 cycles of thermocycling. Increasing the temperature of the composite within biologically compatible limits can significantly influence resin polymerization.[19]

Microhardness is defined as the resistance to permanent deformation only caused by indentation after application of a load. Hardness is overestimated due to elastic recovery when the Vickers microhardness test is used.[20]

According to one pervious study,[5] no significant difference was found between types of matrix bands. In the current study, two composite insertion techniques—incremental and centripetal— were used. While the incremental method has been an acceptable insertion technique for many years, the centripetal method has only been introduced recently. The advantages of this technique include[4,21]

- Facilitation of easier and more rapid placement than conventional techniques
- Creation of an appropriate embrasure
- Improved restoration contour
- Establishment of essential contact points.

However, there were significant differences between these two insertion methods; therefore, only half of the first null hypothesis was accepted.

Use of a transparent matrix along with the centripetal composite insertion technique was found to be significantly superior with respect to surface microhardness of the external layer compared to using the Palodent matrix with the incremental insertion method in this study. This finding is in contrast with a previous study.[4] This might be due to the passage of light through the transparent matrix from other angles, as well as the initial increments of the external layer receiving more light during the polymerization of successive layers using the centripetal insertion method, thus achieving greater hardness. Thus, the second hypothesis was rejected. It seems in the clinical situation the centripetal technique can offer adequate light exposure for polymerization in deep points in the prepared cavity even with the nontransparent Palodent matrix, since it is possible to remove this metal matrix during the restorative procedure.[22]

For all techniques, microhardness was the greatest at the top surface of the restoration, which is in agreement with the results of previous studies.[8,11,23] This might be explained by the relationship between irradiation distance and the effectiveness of polymerization.[24] Therefore, the third hypothesis was rejected. The top surface of the composite material is closer to the light source; therefore, there is no reduction in the light intensity or light scatter compared to the subsequent composite layers, which results in greater hardness values.[25] Increasing the curing light exposure time has been one way to compensate for this problem. Although the differences between the experimental groups in terms of depths and layers were significant, it has been reported that composite curing of deep points in a cavity are considered complete if the minimum hardness value is >80% of maximum value measured on specimen surfaces.[26] The microhardness values of the lower depths and layers were less than for the upper and outer surfaces, but were >80% of maximum value. Therefore, the hardness of various depths and layers might be clinically acceptable if the layer thickness is within 1.5 mm.

It is possible the outermost surface layer of composite might not be cured completely due to exposure to oxygen in the air.[27] Since the specimens in this study were finished and polished (as is the case in most clinical situations), some of the outermost surface material was removed and hardness may be increased. Although the utilization of different wedges or other variables were not examined in this study, it would be interesting to conduct further investigations on this subject.

Conclusions

Within the limitations of this *in vitro* study, it can be concluded the method used to insert composite into a prepared cavity and not the type of matrix used had a significant effect on microhardness. There was a significant difference in microhardness between the experimental groups. The greatest surface mean hardness values for composite restorations were achieved using a transparent matrix and the centripetal insertion method. The top surface had the highest hardness values for all composite insertion techniques used, and the external layer was significantly greater in microhardness using the centripetal composite insertion technique.

Clinical Significance

As the greatest hardness was obtained using the centripetal technique with a transparent matrix, this restorative strategy is recommended. It is clear the microhardness of other experimental placement techniques at the different depths and layers was found to be within a clinically reliable range.

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