ORIGINAL RESEARCH

In Vitro Evaluation of Contact Tightness and Marginal Overhang in Class II Primary Molar Restorations Restored with Different Matrix Systems

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Abstract

Aims and background: Matrix systems are essential for creating the best contacts in class II restorations. The objective of this study is to compare five different matrix systems in class II cavities in terms of proximal contact tightness and marginal overhang.

Materials and methods: A total of 50 standardized second primary model teeth with class II cavities were printed using a three-dimensional (3D) printer. They were divided into five groups ($n = 10$). Resin restorations were made in each group; each tooth was placed on the full teeth model; and the model was placed in the universal testing machine for proximal contact tightness measurement. The maximum friction force was measured by moving an ivory matrix band in the occlusal direction. Digital images were obtained from the interproximal area with a stereomicroscope. Marginal overhang values were obtained by subtracting the cavity borders from the restoration borders. Comparison of mean values between groups was analyzed statistically by the Kruskal–Wallis test. Cohen's effect sizes were calculated for each group analysis.

Results: There was no significant difference between matrix groups in terms of proximal contact tightness ($p = 0.255$). Marginal overhang values in restorations using Tofflemire were found to be significantly lower than Walser, Metafix, and Supercap. Omnimatrix was found to be significantly lower than Metafix and Supercap.

Conclusion: Among these five matrix systems, using the Tofflemire matrix can result in less overhang in primary molar restorations.

Clinical significance: Although various matrix systems are being developed in modern dentistry, it has been observed that the Tofflemire matrix is still reasonable in terms of material overhang.

Keywords: Gingival health, Marginal overhang, Matrix systems, Pediatric dentistry, Primary molars, Proximal contact.

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Introduction

Restoration of the interproximal area as close to natural is one of the primary objectives of a dentist.[1] The greatest challenges encountered in creating class II composite resin restorations include establishing tight interproximal contacts, achieving appropriate contours, and preventing material overhangs in the marginal area of the restoration.[2,3] The contact point is defined as the area in relation to the adjacent tooth, and the main function of a tight contact point is to provide support for the stabilization of the dentition, preserve the interdental papillae, and thereby prevent food impaction and the formation of interproximal caries.[4,5]

Marginal overhang is defined as an extension of the restorative material beyond the borders of the cavity. Restoring, adapting, or polishing these areas is difficult due to limited access to the margins of proximal restorations.[6] Overhanging restorations in the marginal area promote gingival inflammation and lead to decay by locally causing mechanical irritation.[7] Marginal overhangs can be related to the type of restorative material and the matrix technique.[2,8,9]

The difficulties in creating good contact points with compomer and composite resin materials, which cannot be condensed like dental amalgam, can be overcome with modern matrix systems.[10,11] In this study, five different matrices were compared to help create primary tooth restorations with tighter proximal contacts and less overhang.

The Tofflemire matrix is still commonly used. The bands are made of stainless steel in thicknesses of 0.05 and 0.03 mm and are available in straight and contoured shapes.[1] It can be applied from both the facial and lingual surfaces. The matrix holder can be a straight-headed type placed only on the buccal side or a reverse-angled type that can be placed from the buccal/lingual side. Bands produced for mesial–occlusal–distal (MOD) cavities have two bulges at the gingival margin. In traditional Tofflemire systems, a wedge is used in the interproximal area to achieve separation.[12] Composite resin restorations created using Tofflemire matrix tend to trap food due to narrow occlusogingival contacts and straight proximal contours.[8,13] Metafix is a single-use matrix made of 0.038 mm stainless steel, which does not require a separate instrument

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for placement and removal. It is available in three different sizes for premolars and molars. The form with a transparent band has been offered under the name Lucifix by the same manufacturer.[14] After the band is placed, it is tightened starting from the part closest to the tooth using a ring-shaped holder.[15] Supercap matrix bands are purchased with an application gun. The bands are disposable and made of steel or transparent plastic.[15] Steel matrices are produced in thicknesses of 0.030, 0.038, and 0.05 mm.[16] They provide a more rounded proximal contour. The matrix can be easily directed buccally or palatally/lingually and allows the wedge to be placed from any angle. These systems help to keep the rubber dam in place and improve access to the cavity.[17] The single-use Omnimatrix is available in four sizes—(1) purple, (2) red, (3) green, and (4) orange—made of transparent plastic and stainless steel. The size of the circumferential band is adjusted by turning the colored conical end portions.[15] The Walser matrix system has 25 matrices for restoring classes II, III, and IV cavities and adjacent proximal surfaces at the same time. The bands have a spring mechanism for a tight fit and do not require wedges, according to the manufacturer's guide.[18,19]

Materials and Methods

A total of 50 model teeth with standard class II cavities were divided into five groups. Each group received composite resin and compomer restorations using one of five matrices: (1) Tofflemire, (2) Omnimatrix, (3) Metafix, (4) Supercap, or (5) Walser. Proximal contact tightness and marginal overhang were compared. Composite resin and compomer were selected for their common use in pediatric dentistry:

- In group I, Tofflemire matrix (Hahnenkratt, Germany) is used with a contoured 0.038-mm thickness band (KerrHawe, Switzerland).
- In group II, Omnimatrix (Ultradent, USA) is used which has a 0.038-mm band thickness (purple).
- In group III, Metafix (KerrHawe, Switzerland) is used which has a 0.038-mm band thickness (small).
- In group IV, Adapt Supercap (KerrHawe, Switzerland) is used which has a 0.038-mm band thickness (blue).
- In group V, Walser matrix (Walser Dental, Germany) is used which has a 0.05-mm band thickness (O-form, number 9).

Preparation of the Samples

A mesioocclusal cavity was prepared on the lower right second primary molar of a pediatric model from Frasaco, Germany. The proximal cavity dimensions were 2.5 mm buccolingually, 3 mm occlusogingivally, and 1 mm mesiodistally. To standardize the cavity dimensions, the prepared tooth was duplicated in permanent crown resin from Formlabs Dental, USA, using a Form 3B printer to create 50 replicas. The adjacent primary first molar was restored with a stainless steel crown to prevent damage to the distal tooth surface during cavity restoration and contact tightness measurements.

Detection of Cavity Margins at the Interproximal Area

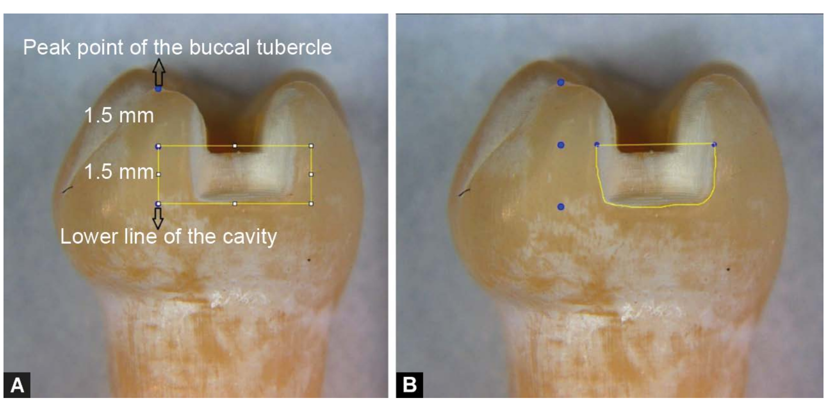
Marginal overhang was measured in studies by Loomans et al. in 2009 and 2012 using a stereomicroscope. Images taken before and after restoration were compared.[2,9] The model tooth was positioned parallel to the horizontal plane, and digital images were captured from the interproximal area using a Leica M205 C Trinocular stereomicroscope at 10× magnification. These images were then processed in the image analysis program Fiji. Borders were marked, and area calculations were performed. Fiji is an open-source version of ImageJ, commonly used for biological research, which includes plugins for image analysis.[20,21]

To ensure consistent border measurements, the peak point of the buccal tubercle and the lower line of the cavity in the occlusogingival direction were marked. The occlusogingival height was set at 3 mm. Since material overhangs near the occlusal area can be removed during polishing but gingival region overhangs cannot, the gingival half of the cavity was used for marginal overhang calculation. The area of the gingival half of the cavity was measured to be 4.423 mm^2 (Fig. 1), which will be used in the calculation of marginal overhang.

Restoration of the Samples

A total of 50 model teeth were divided into five groups, with five composite resin and five compomer restorations in each group. Tofflemire, Omnimatrix, Metafix, and Supercap matrices were adapted, followed by the use of a buccally inserted wedge (small size, Premium Plus, USA). For the Walser matrix, no wedge was used per the manufacturer's recommendations.

For the restorations, a universal bond (G-Premio Bond, GC, Japan) was used and polymerized with light-emitting diode (LED) curing unit (Woodpecker LED G, Guilin Woodpecker, China) for 10 seconds. The compomer (Dyract XP, Dentsply Sirona, USA) and composite resin (Estelite Posterior Quick, Tokuyama Dental, Japan) were applied using a layering technique in three stages, with an average size of 1–1.5 mm. Layering began from the proximal cavity, and in each stage, light was applied from the occlusal direction for 20 seconds as per the manufacturer's instructions.



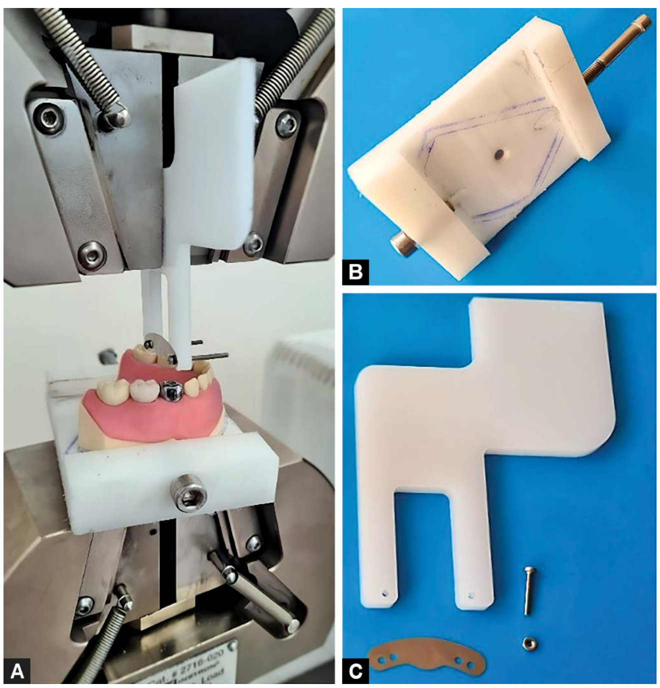
Figs 1A and B: (A) Marking of the peak point of the buccal tubercle and the lower line of the cavity; (B) Drawing the borders of the gingival half of the cavity

All restorations were performed by a single operator, and to prevent interference with the measurements, they were not polished afterward.

Measurement of Proximal Contact Tightness

The first device for measuring proximal contact tightness in *in vitro* conditions was used in studies by Loomans et al. in 2006 and was designed at Delft University of Technology.[11,22]

The tightness of the contact point was considered as the maximum frictional force (N) applied to the two-hole, 0.04-mm thick ivory matrix band (Hahnenkratt, Germany) when it is moved in the occlusal direction interproximally. A computer-controlled Instron 3369 universal testing machine with a tensile–compressive capacity of 50 kN was set to move in the occlusal direction at a rate of 5 mm/minute. To be able to apply the metal band to the interdental area and standardize its occlusal movement, the plastic model was mounted on a specially designed stand. Plastic stands were prepared specifically for the adaptations of the metal ivory matrix band to the upper arm and for the stabilization of the model to the lower arm of the testing machine, at the Manufacturing Department of the Faculty of Technology, Gazi University (Fig. 2).



Figs 2A to C: (A) Measurement of proximal contact tightness with the universal testing machine; (B) The platform on which the model is fixed; (C) Adaptation of the measurement band to the device

For each restoration, three measurement procedures were performed, and the averages were taken. The tooth was removed from its socket and repositioned between the three measurements. If the maximum range of 0.5 N was exceeded, the measurement was considered unsuccessful. This different measurement value, which was seen due to the deformation of the metal band, nonparallel movement from the interproximal, or displacement in the plastic model, was then subtracted from the data and repeated. The collected data were transferred to Excel (MS Office 2013, Windows) and used to create diagrams related to force and seconds.

Measurement of Marginal Overhangs

After restoration, digital images of the interproximal of each sample were obtained using a Leica M205 C trinocular stereomicroscope at 10× magnification. These images were transferred to Fiji software, where brightness, contrast, and color adjustments were made to ensure the clearest visibility of the borders. The gingival half of the restoration border was marked (Fig. 3). The surface area of the cavity preparation previously measured (4.423 mm^2) was subtracted from the restoration surface area to determine the marginal overhang values. All measurements were performed blindly by an independent observer (BA).

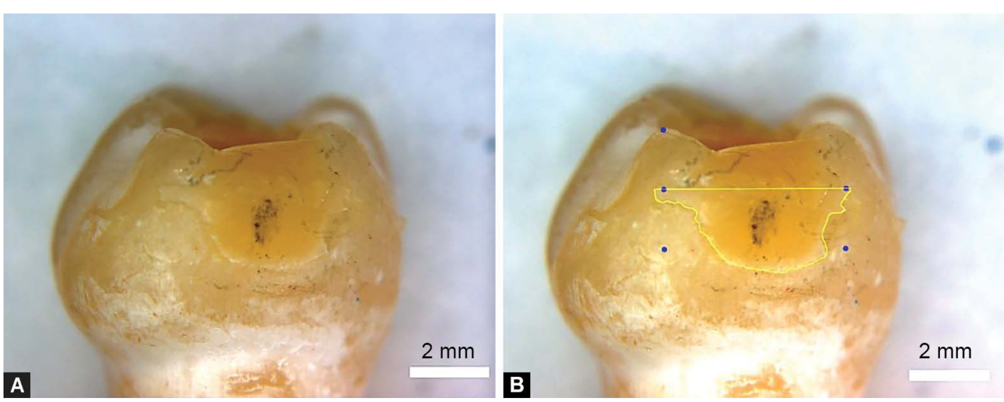
Statistical Analysis

The normality assumption was assessed using the Shapiro–Wilk test. For variables that did not follow a normal distribution, the Kruskal–Wallis test was used to compare means. The *post hoc* Bonferroni test was then applied to identify the specific groups that differed. Data analysis was conducted using IBM SPSS Statistics 25.

In this study, Cohen's effect sizes were calculated. The definitions of effect sizes for the independent samples *t*-test are small (0.2), medium (0.5), large (0.8); the analysis of variance (ANOVA) tests are small (0.1), medium (0.25), and large (0.8).[23]

Results

Proximal contact tightness values were obtained in Newton as the maximum frictional force, and the comparison of the means is shown in Table 1. There was no statistically significant difference in the mean proximal contact tightness values between groups based on the matrix systems ($p = 0.255$). The effect size was 0.098, which is determined to be small.



Figs 3A and B: (A) Stereoscopic view of the restoration; (B) Borders of the gingival half of the restoration

Table 1: Comparison of the mean proximal contact tightness values according to matrix systems

	Proximal contact tightness			
	n	*Mean (standard deviation)*	*p*	*Effect size*
Group I (Tofflemire)	10	1.6133 (0.42261)	0.255	0.098
Group II (Omnimatrix)	10	1.6558 (0.40270)		
Group III (Metafix)	10	1.7990 (0.46269)		
Group IV (Supercap)	10	1.4101 (0.48836)		
Group V (Walser)	10	1.5198 (0.27910)		

The significance level was 0.05

Table 2: Comparison of the mean marginal overhang values according to matrix systems

	Marginal overhang			
	n	*Mean (standard deviation)*	*p*	*Effect size*
Group I (Tofflemire)	10	1.0948^{b} (0.30402)	0.000*	0.723
Group II (Omnimatrix)	10	$1.7290^{b,c}$ (0.48386)		
Group III (Metafix)	10	4.5691^{a} (0.87225)		
Group IV (Supercap)	10	5.0303^{a} (1.80053)		
Group V (Walser)	10	$3.0472^{a,c}$ (0.81486)		

The significance level was 0.05; *$p < 0.05$; Identical characters (a, b, c) indicate that there is no statistically significant difference between the matrices ($p < 0.05$)

Marginal overhang values were measured in square millimeters, and the means are compared in Table 2. Identical characters (a, b, c) indicate that there is no statistically significant difference between the matrices ($p < 0.05$). There is a statistically significant difference in the mean marginal overhang values between groups according to the matrix systems ($p \sim 0.000$). The effect size was 0.723, which is considered to be high.

The mean marginal overhang values of groups III and IV were statistically significantly higher than those of groups I and II, and the mean marginal overhang value of group V was statistically significantly higher than that of group I ($p = 0.013$, $p = 0.000$, $p = 0.002$, $p = 0.002$, and $p = 0.00$). There was no statistically significant difference between groups I and II; groups III, IV, and V; and groups II and V ($p > 0.05$).

Discussion

Proximal contact tightness is a multifactorial value influenced by factors, such as tooth type, position, time of day, patient position, chewing, and restorative procedures.[3,24,25] In natural dentition, proximal contact tightness varies widely between individuals, ranging from 0.10 to 12.43 N. Therefore, an optimal value cannot be given for proximal contact tightness.[10] In *in vitro* studies, it is possible to measure proximal contact tightness with a model by ensuring standardization.[22]

A model cannot fully replicate the physiological tooth movement; as a result, studies under *in vitro* conditions may underestimate the amount of marginal overhang in the oral environment.[2] On the contrary, the rigidity of teeth in the model allows for the evaluation of each matrix under the same conditions.[26]

For standardization, the cavities on the model teeth need to be the same. Printed teeth could be used instead of extracted or plastic model teeth.[27,28] Additive manufacturing is advantageous because of its high success rate, being more economical than ceramic samples created using a copy milling machine, and providing faster access to the sample.[28] In this study, three-dimensional (3D) printing technology was preferred for duplicating the samples and standardizing the cavity preparation.

Restorations made with circumferential matrices result in statistically significantly lower proximal contact tightness compared to sectional matrices. When a circumferential matrix is placed, it occupies a total of 0.07–0.10 mm both mesially and distally, while the thickness of the sectional matrix systems remains between 0.04 and 0.05 mm because they are placed either mesially or distally.[22] In our study, circumferential matrices were compared except for the Walser matrix. An O-form Walser matrix was preferred, which contains a band adapted both mesially and distally, similar to circumferential bands.

Primary teeth have a significant cervical constriction and wider, flatter contact areas compared to permanent teeth. This increases the risk of matrix bands shifting and makes their placement more challenging.[29] Therefore, matrix bands may not be placed as easily in primary teeth. This difficulty can be overcome by using wedges or separation rings with the matrices.[26] In our study, a buccally contoured plastic wedge was used, except for the Walser sectional matrix, following the manufacturer's instructions.

Low-intensity light curing units have been shown to cause less polymerization shrinkage and have an effect on proximal contact tightness compared to high-intensity light curing units.[30] In this study, polymerization was achieved with a standard, fixed light intensity.

In this study, the thickness of the matrix bands used in the restorative phase is on average 0.038 mm. It is estimated that a gap is created during restoration equal to the thickness of the matrix band placed between adjacent teeth. Therefore, it was decided that the thickness of the band moved interdentally during the measurement of proximal contact tightness should be 0.04 mm, which was close to the thickness of the band used during restoration.

In a study investigating the effect of the combined use of sectional and circumferential matrices with separation rings on proximal contact tightness, it was concluded, similar to our study, that Walser failed to provide tight proximal contact (mean 1.34 ± 0.55 N).[30] In our study, it can be seen that the proximal contact tightness values of restorations created using Walser do not create a significant difference compared to restorations created using other matrix types.

Saber et al. in 2011 compared Walser with a sectional matrix used with a separation ring and achieved significantly lower proximal contact tightness values with Walser.[18] In the study by Loomans et al. in 2006, it was observed that the use of Supercap and sectional matrices instead of Tofflemire did not create a significant difference in proximal contact tightness values.[11] In the study by Kampouropoulos et al. in 2010, there was no significant difference in proximal contact tightness values between Tofflemire matrix, metal Supercap, and transparent Supercap matrices.[26] In the presented study, restorations created using Supercap yielded the lowest proximal contact tightness values, but this difference, consistent with the studies in 2006 and 2010, did not create a significant difference compared to Tofflemire matrices.

In previous studies, it has been reported that every restoration results in some marginal overhangs.[2,9,31–34] Also in this study, each primary tooth restoration resulted in marginal overhangs. Higher marginal overhang values were achieved compared to permanent teeth. This difference could be attributed to the morphology of primary molars, which exhibit a higher degree of tapering at the cervical area and a significant curvature on the buccal surface. When the matrix band around the primary molar is fixed with a wedge for adaptation, it creates a wider space between the buccal and lingual walls of the cavity and the matrix band. This space is filled by the restoration material, which increases in excess toward the occlusal and can be reduced by polishing.

In a study by Loomans et al. in 2009 comparing circumferential matrices (Tofflemire and Supercap) with sectional matrices in terms of marginal overhang, it was stated that the use of circumferential matrices resulted in less overhang compared to sectional matrices. While the use of the Supercap matrix alone resulted in more overhang than Tofflemire, the use of the Supercap matrix with a separation ring resulted in less overhang than Tofflemire.[2] In our study, restorations created using Tofflemire showed the lowest marginal overhang values, which were significantly lower compared to Supercap.

The comparison of the compomer and composite resins used as filling materials was not conducted in the study. Increasing the sample size and comparing the filling materials require further research.

Conclusion

- There was no significant difference in proximal contact tightness values among restorations using Tofflemire, Omnimatrix, Metafix, Supercap, and Walser matrices.
- Marginal overhang was observed in all groups. Restorations created using Tofflemire matrices resulted in the lowest, while those created using Supercap matrices resulted in the highest marginal overhang values.
- In restorations using Tofflemire matrices, the marginal overhang values were significantly lower than those using Walser, Metafix, and Supercap, while in restorations using Omnimatrix matrices, they were significantly lower than those using Metafix and Supercap.
- Tofflemire seems to be a better choice in primary molar restorations to use to protect gingival health and prevent secondary caries, as it causes the lowest marginal overhang among these five matrix systems.
- Contact point and marginal adaptation, which greatly affect the success of restorations, can be successfully recreated by selecting the most suitable matrix system for primary tooth morphology. This study provides guiding information for clinicians to choose the appropriate matrix system for interproximal restorations in primary teeth.

Clinical Significance

Matrix selection is very important in order not to reduce the clinician's success with overhanging or loose contact restorations, especially in children who cannot maintain proper oral hygiene. Various matrix systems are being developed in modern dentistry. This study shows that the use of the traditional Tofflemire matrix in primary teeth is still a good choice.

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