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Proximal Contact Tightness Between Direct-composite Additions in the Posterior Dentition: An *In Vitro* Investigation

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Clinical Relevance

A novel three-step matrix technique for the application of posterior direct-composite additions was tested *in vitro*. It was proven that by using this technique the reconstruction of proximal contacts and the creation of well-contoured proximal surfaces between direct-composite additions are feasible in an *in vitro* setting. The preclinical testing of this novel technique is necessary to establish the work flow for clinical application and to acquire data for planning *in vivo* investigations.

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SUMMARY

Purpose: The aim of the study was to test whether a novel three-step matrix technique for posterior direct-composite additions creates sufficiently strong proximal contacts.

Materials and Methods: Contact tightness was measured between direct-composite additions and between original teeth on a model. Therefore, the frictional forces required to remove a straight, 0.05-mm-thick, metal matrix band inserted between adjacent teeth and held by a universal testing machine (Zwicki, Zwick GmbH, Ulm, Germany) were recorded. Measurements were taken at three time points to carry out reference analysis: at baseline, after removal of the maxillary right second premolar (tooth #15) to simulate a diastema, and after closure of the diastema by inserting two direct-composite additions with the three-step matrix

technique on the maxillary right first premolar (tooth #14) and first molar (tooth #16). Measurements were performed in the maxillary right (first) and left (second) quadrants to document sagittal displacement.

Results: The original contact tightness values were between 1.65 ± 0.88 N and 3.05 ± 0.60 N in the first quadrant and between 1.23 ± 0.51 N and 2.18 ± 0.43 N in the second quadrant. After removal of tooth 15, values decreased significantly in the first quadrant and insignificantly in the second. After reconstruction, the contact tightness between teeth 14 and 16 was significantly stronger (tighter) (3.20 ± 0.80 N) than the originally measured contact tightness between teeth 14 and 15 (2.86 ± 0.64 N) and teeth 15 and 16 (1.65 ± 0.88 N) (*p*=0.006 and 0.001, respectively).

Conclusions: Within the limitations of an *in vitro* investigation, this study has shown that by using a novel, three-step matrix technique, direct posterior composite additions can form sufficiently tight proximal contacts.

INTRODUCTION

Today, single missing teeth are generally replaced by conventional fixed prostheses or implants. In recent years, additional treatment options, such as direct-composite additions,[1-4] have been introduced whereby a diastema can be closed by adding composite resin on the proximal surface of one or both adjacent teeth. In addition, this technique facilitates correction of malformed or misaligned teeth.

In the course of steady advancement in the application of composite resin techniques, these restorations have become increasingly useful.[3] The development of specific matrix techniques for insertion of direct-composite additions to anterior teeth has greatly helped optimize functional and esthetic results. The proximal forming technique,[5] for example, involves the application of a translucent matrix band, which is fixed cervically and interproximally, helping to create a natural proximal tooth form. The clinical success of anterior direct-composite additions has been reported in three clinical studies[1,2,6] that offer promising long-term results.

The closing of diastemas in the posterior area was described by Vest as early as 1951.[7] In order to close a 4-mm diastema, Vest placed full crowns on the adjacent teeth, expanding them 2 mm into the gap. Staehle[3] refined the technique by substituting the crowns with direct-composite additions using a three-step matrix technique.[8] This novel concept (the step-by-step procedure is described below) included the successive application of straight circumferential matrices (AutoMatrix®, Dentsply DeTrey GmbH, Konstanz, Germany) and a sectional, contoured matrix (Palodent®, Dentsply DeTrey). The choice of matrix types has evolved from clinical practice over the years (see the example of a clinical case with a 7.5-year follow-up period; Figure 1). Standardizing this process permitted the fabrication of well-contoured composite additions without proximal resin overhangs or gaps between tooth and restoration. Furthermore, wedging, applying a separating ring, and additional separation by hand made the creation of strong contact tightness possible, allowing the patient to avoid subsequent food impaction or periodontal breakdown.[9,10]

Large composite additions must withstand occlusal loads on the marginal ridges, especially in cases where a wide diastema of several millimeters must be bridged, making support by a well-contoured proximal segment necessary. It has been shown[11] that on Class II restorations, marginal ridges can be loaded significantly higher when supported by convex, contoured proximal segments. However, to our knowledge, the size of such a resistant proximal segment remains undefined. Therefore, we aimed at forming the direct-composite additions to such an extent that the proximal contour was as convex as possible, leaving enough space for the interdental papilla and for interdental cleaning procedures.

Experimental evidence about the advantages of this novel technique—that is, creation of tight contacts and good proximal shape of the restorations—is still lacking. Therefore, the aim of this study was to test whether posterior direct-composite additions inserted with the three-step matrix technique can reestablish a proximal contact tightness similar to that measured between the model teeth of the intact KaVo model. Additionally, data on changes in contact tightness between adjacent and contralateral teeth at different time points were assessed to describe the effect of a simulated missing tooth and of a reestablished proximal contact on the displacement of teeth within the dental arch. Our hypothesis was that posterior direct-composite additions inserted with the three-step matrix technique could form well-contoured proximal contacts that are as tight as the original contacts on the model.

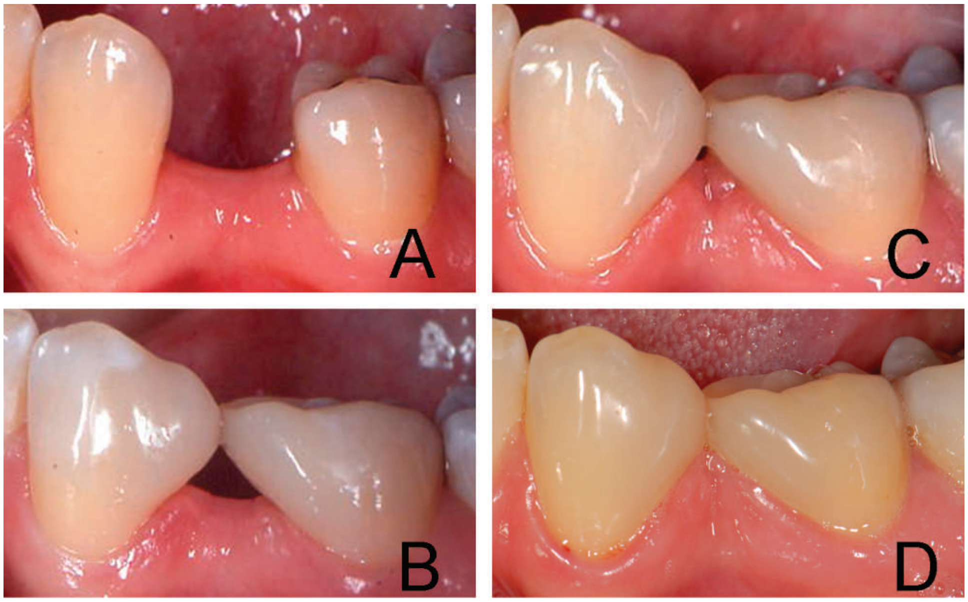

Figure 1. *Clinical case showing direct-composite additions on the mandibular left canine and second premolar. (A): Baseline situation; (B): clinical situation directly after insertion of the direct-composite additions; (C): clinical situation at recall appointment six months after treatment; and (D): 7.5 years after treatment.*

MATERIALS AND METHODS

In order to standardize the restorative procedure and to simulate the clinical situation, an intraoral model for preclinical student exercise courses (KaVo Basic Model, KaVo Dental GmbH, Biberach, Germany) was used. In this setup, the artificial teeth are clicked into the model, and they display reproducible tooth mobility corresponding to a physiological range (internal data). For the experiments, the maxillary right first (tooth #14) and second (tooth #15) premolars and first molar (tooth #16) were selected. The definition of the terms "proximal contact" and "proximal contact tightness" can be found in Table 1. To measure the proximal contact tightness, the model was mounted in a custom-made, highly reproducible setup that allowed for standardized measurement of all contact areas of interest. Proximal contact tightness was measured using a universal testing machine (Zwicki, Zwick GmbH, Ulm, Germany). A straight metal matrix (0.05 mm thick; Hawe Tofflemire, KerrHawe, Bioggio, Switzerland) was inserted interdentally from the occlusal direction and pulled out by the machine (50 mm/min; Figure 2). To avoid false measurements or artifacts due to deformation or nonparallel removal, the matrix was positioned free of tension in the interproximal area 1 mm above the artificial gingiva. The tightness of the proximal contact was quantified as the maximum frictional force [F_{max} (N); Figure 3] exerted during vertical removal of the matrix.[12]

Measurements were carried out in the first quadrant between tooth pairs 13/14, 14/15, 15/16,

Table 1: *Definition of Terms*

Term	Definition
Proximal contact	The area where adjacent teeth touch each other
Proximal contact tightness	The maximum frictional force [F_{max}, (N)] exerted during vertical removal of a straight metal matrix

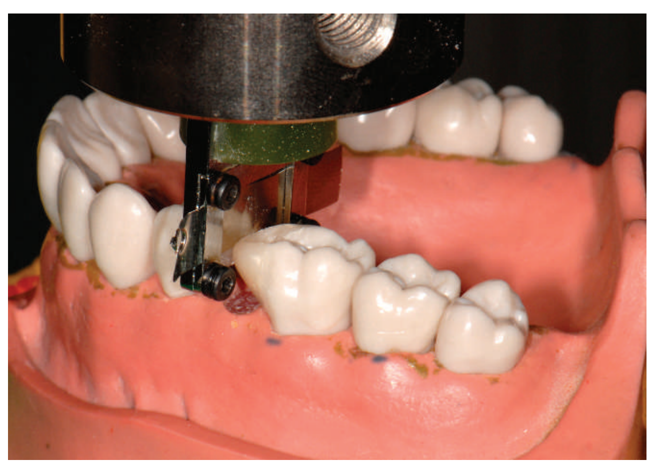

Figure 2. *Measuring contact tightness between direct-composite additions on teeth 14 and 16 with a universal testing machine (Zwicki, Zwick GmbH, Ulm, Germany).*

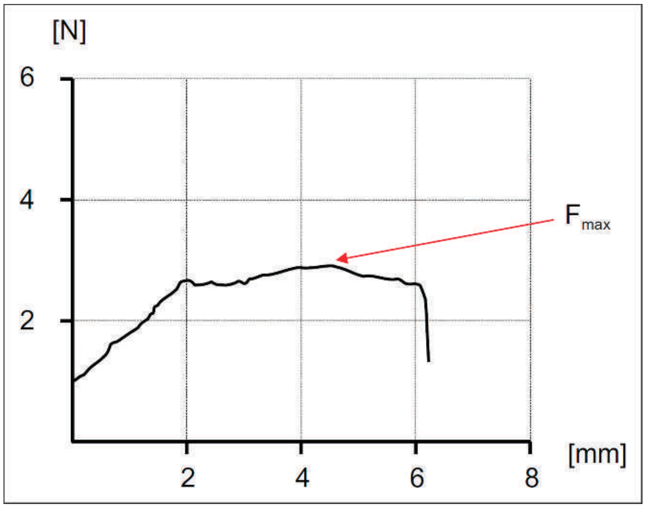

Figure 3. *Graph produced by the universal testing machine showing distance-force relation. The maximum force (F_{max}) is recorded as contact tightness.*

and 16/17; in the second quadrant, measurements were carried out between tooth pairs 23/24, 24/25, 25/26, and 26/27 (Figure 4). Baseline data were marked with the suffix "_1." Subsequently, tooth 15 was removed, and the measurements were carried out again. The data were labeled "_2" (Figure 5). After insertion of the direct-composite additions on teeth 14 and 16 following the three-step matrix technique (standardized protocol described by Staehle[13]; short description below), measurements of contact tightness were repeated. Final data were labeled "_3" (Figure 6).

Since no previous data on contact tightness of composite resin additions were available, this investigation was planned as a pilot study with a sample size of n = 30. Descriptive data analysis (precondition: normal distribution) was used to determine the arithmetic mean (Mean) and standard deviation (SD) of contact tightness at different locations and at the time points "_1," "_2," and "_3." Differences between contact tightness at corresponding locations were tested for significance with a paired *t*-test (two-sided significance; $p=0.05$).

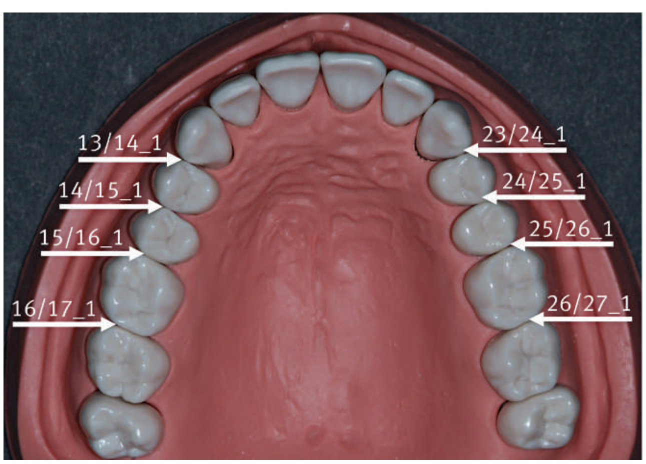

Figure 4. *Model with indicated baseline measurement points.*

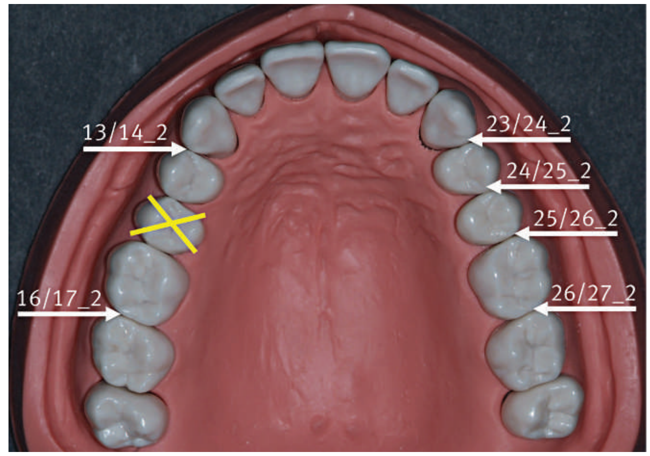

Figure 5. *Model with indicated measurement points after removal of tooth 15.*

Three-Step Matrix Technique

Prearrangement—The prearrangement steps included the following:

- Application of rubber dam
- Proximal adhesive surfaces were cleaned, roughened, and prepared for treatment with an adhesive system (Optibond FL®, KerrHawe).

First Step—The first step comprised the following:

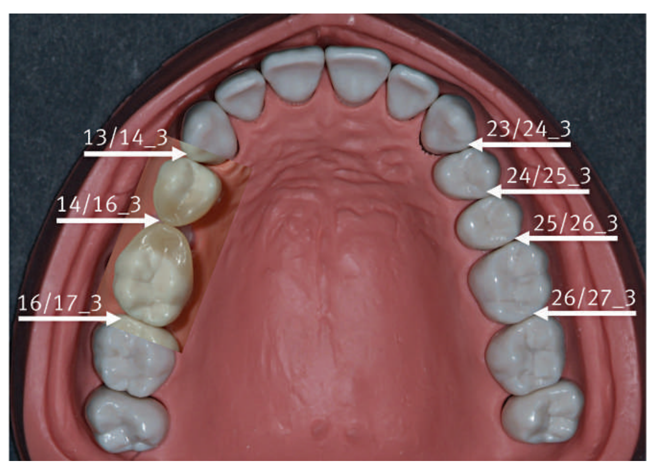

Figure 6. *Model with indicated measurement points after insertion of composite additions on teeth 14 and 16.*

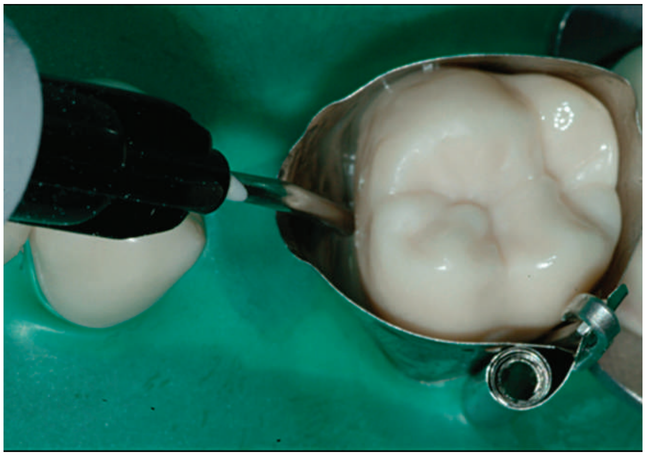

Figure 7. *Three-step matrix technique. First step: A straight circumferential matrix is fixed around tooth 16, "bulged out" toward tooth 14, and the first layer of flowable composite resin is applied.*

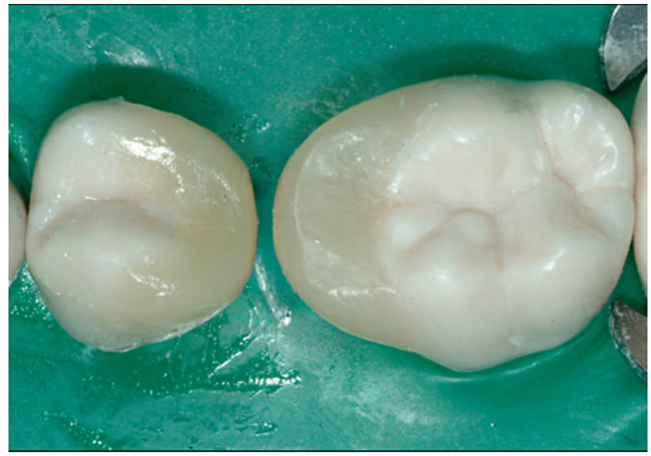

Figure 9. *Three-step matrix technique. Second step: Completion of this step reduces the interspace between teeth 14 and 16 to 0.5-1.0 mm.*

- A straight circumferential matrix (AutoMatrix®, Dentsply DeTrey) was applied on tooth 16 and "bulged out" toward tooth 14 using hand instruments. The cervical part of the restoration was built up with a layer of flowable composite resin (Figure 7) and a layer of viscous composite resin. With this technique, a gap-less transition from tooth to restoration was created.
- After removal of the matrix, the restoration was layered by hand with viscous composite resin (Figure 8) and polished.
- At this point, the interspace between teeth 14 and 16 had been reduced to half its original size (Figure 8).

Figure 8. *Three-step matrix technique. First step (continued): Direct composite is layered using viscous resin, filling half the interspace between teeth 14 and 16.*

Second Step—The second step comprised the following:

- A straight circumferential matrix (AutoMatrix®) was applied on tooth 14 and bulged out toward tooth 16. The restoration was layered as described above.
- Here, two important comments must be made. First, at the end of the second step, an interspace of 0.5-1 mm was left between teeth 14 and 16 (Figure 9), and second, no polishing of the composite resin was done in order to maintain the oxygen inhibition layer for the next step.

Third Step—The third step comprised the following:

- To bridge the remaining interspace, a sectional, contoured matrix and an oval separating ring (Palodent®, Dentsply DeTrey) were applied on tooth 14. To ensure contact tightness, additional separating force was applied by twisting a hand instrument during light polymerization of the first layer of flowable composite resin (Figure 10, red arrow). Subsequently, viscous composite resin was applied and the restoration was completed.
- Final adjustment and polishing were done (Figure 11).

RESULTS

Analysis of the collected data showed that teeth 16/17 and 25/26 were set in the model in such a way that they did not form regular contacts. Therefore, no valid measurements were possible and those variables were excluded from further analysis.

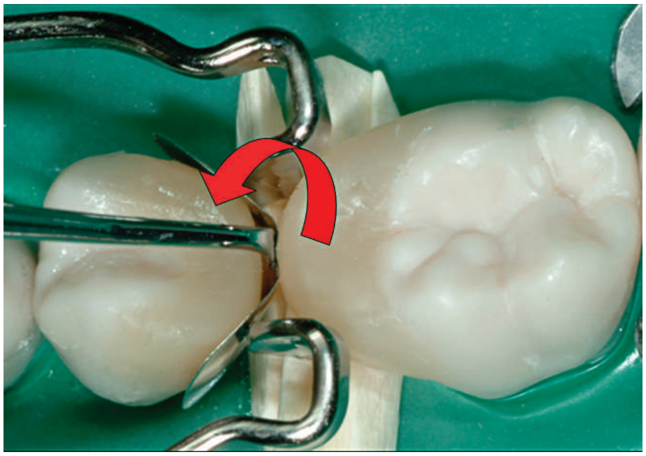

Figure 10. *Three-step matrix technique. Third step: A sectional contoured matrix, wedges, and an oval separating ring are applied on tooth 14. The remaining interspace between teeth 14 and 16 is filled with resin composite. During light polymerization, additional separating force is applied by twisting a hand instrument (red arrow).*

In the first quadrant, baseline measurements showed the highest proximal contact tightness between 13/14 (3.05 ± 0.60 N). The decrease in contact tightness after removal of tooth 15 and the increase after reconstruction of teeth 14 and 16 are shown in Figure 12 and Table 2. In the second quadrant, the baseline values were generally lower, decreasing slightly after removal of tooth 15 and reaching their original values again during final measurement (Table 2; Figure 13).

A paired *t*-test was performed to test for differences in contact tightness at corresponding proximal areas between baseline and final measurements. Values were checked for two-sided significance. Only the paired variables 14/15_1 and 14/16_3, as well as 15/16_1 and 14/16_3, yielded significant differences (p=0.006 and 0.001, respectively; Table 3).

Figure 11. *Model situations before (top) and after (bottom) insertion of direct composite resin additions on teeth 14 and 16.*

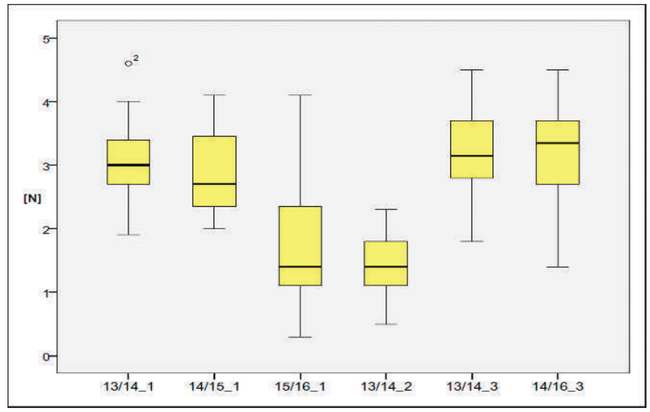

Figure 12. *Box plot of data from measurements in the first quadrant.*

DISCUSSION

Direct-composite additions have become a significant tool in dentistry, especially for healthy teeth needing esthetic correction, for which a maximal tooth-saving approach is imperative.[1,2,6] Both patients and dentists can benefit from the advantages of this treatment option, which include the following: 1) tooth shape, color, and position can be corrected with an immediate restoration in a single treatment session; 2) the technique is either noninvasive or

Table 2: *Proximal Contact Tightness at Different Locations and Time Points (_1=Baseline; _2=After Removal of 15; _3=After Insertion of Composite Resin Additions on Teeth 14 and 16)*

Location	Time of Measurement		
	_1	_2	_3
	Mean ± Standard Deviation, [N]		
13/14	3.05 ± 0.60	1.40 ± 0.47	3.20 ± 0.70
14/15	2.86 ± 0.64		
15/16	1.65 ± 0.88		
14/16			3.20 ± 0.80
23/24	1.23 ± 0.51	1.07 ± 0.42	1.23 ± 0.47
24/25	1.43 ± 0.45	1.34 ± 0.39	1.47 ± 0.33
26/27	2.18 ± 0.43	2.08 ± 0.42	2.16 ± 0.32

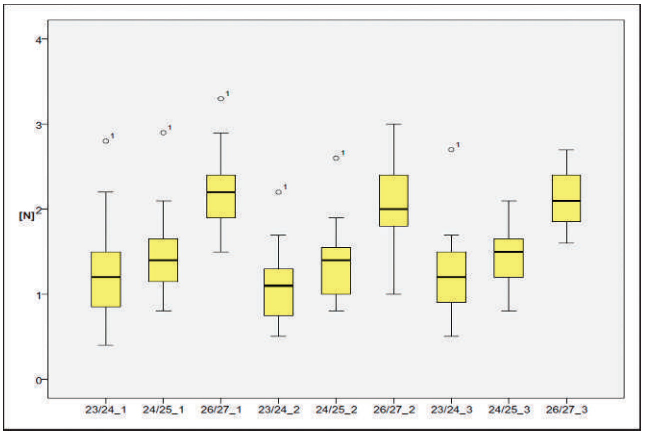

Figure 13. *Box plot of data from measurements in the second quadrant.*

Table 3: *Results of Paired t-Test (Two-Sided Significance)*

Pair	*p*-Value
13/14_1–13/14_3	0.108
14/15_1–14/16_3	0.006
15/16_1–14/16_3	0.001
23/24_1–23/24_3	0.808
24/25_1–24/25_3	0.377
26/27_1–26/27_3	0.891

minimally invasive; 3) restorations can be removed and teeth returned to their original state, if necessary[14]; and 4) in case of minor failure, the restoration can be repaired with little effort, and in case of major failure (loss of restoration), other treatment options (implants, crowns, bridges) can be applied. Numerous case reports[3,15-18] related to direct-composite additions to close diastemas, recontour teeth, and change tooth color have presented excellent clinical results. Yet standardized fabrication procedures ensuring good esthetic, functional, and biological outcome—especially for the correction of posterior teeth—are still lacking.

Therefore, we have investigated, in an experimental setup, a novel, three-step matrix technique for posterior direct-composite additions in order to determine its potential for reconstructing well-contoured proximal surfaces and good proximal contacts. Our hypothesis—that the proximal contact between two adjacent composite resin additions bridging an interspace of a removed premolar can be made at least as tight as the original contact—has been proven. The newly created contact was even tighter than that of the original proximal contacts.

Unlike amalgam, composite resin is not condensable, making the reconstruction of good proximal contacts with this material complicated. The results of a questionnaire completed by German dental students showed that shaping the proximal contact areas creates the most problems during insertion of Class II resin restorations (86%) and that a low proximal contact is one of the most frequently reported failures (43%) of those restorations.[19] To overcome this problem, contoured sectional matrices and special devices such as separating rings were developed. An investigation[20] of their separation potential compared with that of wedges showed significantly more separation, allowing for tighter proximal contacts. Today, after the introduction of sectional contoured matrices and separating rings, the risk of failure due to weak proximal contacts and inferior proximal shape has declined.

However, posterior composite additions must bridge interspaces larger than that of conventional Class II restorations, further complicating reconstruction. Therefore, a novel matrix technique involving the successive application of three matrices, wedges, and a separating ring was developed. This technique enabled us to achieve very tight proximal contacts in the experimental setup. Compared with natural proximal contact tightness in patients investigated by Dorfer and others,[21] which lie in the range of 2.0 $\pm$ 1.6 N and 4.9 $\pm$ 1.9 N, the recorded values were still acceptable. Within certain limits, an increase in contact tightness can be influenced by the separation intensity applied by the dentist during the last step of the three-step matrix technique. Loomans and others[22] found that when contact tightness is increased after insertion of Class II resin restorations, it will decrease over time (as a result of wear of the proximal resin composite surfaces), whereas reduced contact tightness is not compensated. Since in clinical practice reconstruction of precisely the original contact tightness is difficult to achieve, a slight increase seems to be a useful approach.

The clinical case presented in Figure 1 displays two quite large direct-composite additions ("balconies") that bridge the gap. Here, the issue of whether cohesive strengths of these restorations are able to withstand occlusal loading might arise. It was shown[11] that convex shaping of Class II restorations statistically significantly increases their load-bearing capacity. Therefore, the presented technique aims at creating convex-shaped proximal surfaces that provide sufficient support against cohesive failure. Furthermore, we recommend fabricating the direct-composite additions in such a way that the creation of novel occlusal contacts is avoided. The original contacts that are present before therapy should be maintained and the functional situation should not be altered. This approach protects the direct-composite additions from overstressing and failure.

The preclinical testing and the experiences with clinical application that we have gained over years helped us to define therapeutic indications. We recommend direct-composite additions in the posterior dentition when a gap of up to the width of one premolar (up to approximately 8 mm) has to be closed. Consequently, this treatment has become an alternative to implants or fixed dental prostheses. In our opinion there are no limitations concerning angulations of teeth or long clinical crowns. The mere addition of composite resin to teeth without any preparation does not compromise tooth integrity. An esthetic improvement is achieved, the functional situation is not altered, and we have observed that in several clinical cases the biological parameters have improved over the years (Figure 1). It is, however, crucial to reestablish sufficient proximal contacts to ensure sagittal support for the restored teeth. Otherwise, masticatory forces applied on the direct-composite additions could lead to a detrimental loading situation, comparable to that associated with cantilever fixed dental prostheses. When selecting patients it should be considered that the oral hygiene situation must be good. Patients must be trained in oral hygiene procedures and continuously supervised, and size-adjusted interdental brushes should be used. Then this kind of restorative procedure involves benefits for patients of all age groups who prefer noninvasive or minimally invasive treatment approaches. In comparison to other treatment alternatives, the procedure is very cost-effective since no laboratory work is necessary. As a result of the reported benefits, we suggest that practitioners expand the therapeutic indications and consider the three-step matrix technique (or a modification of it) for use in those clinical cases in which large class II cavities must be restored. In such a situation, a multiple-step matrix technique is reasonable to first reconstruct the cervical parts of the cavity and subsequently reestablish the proximal contacts.

As a second objective, the sagittal displacement of teeth in the model was investigated to determine the effect on the adjacent and contralateral contacts of removing tooth 15 and reconstructing teeth 14 and 16. The universal testing machine basically measured how much friction was present between adjacent proximal surfaces. When a gap (missing tooth) is present and the subsequent proximal contact is measured, the one tooth next to the gap can move aside, leading to a decrease in frictional force (= decrease in contact tightness). This phenomenon seems to continue throughout the dental arch, leading to a reduction in contact tightness even on the contralateral side. As expected, removal of tooth 15 led to a significant reduction in contact tightness in the first quadrant and to insignificant reduction in the second quadrant.[23] The reestablishment of a new tight proximal contact, however, did not lead to an increase in contact tightness at adjacent and contralateral proximal contacts. After insertion of the composite additions, all baseline tightness values were restored, illustrating that the contact tightness increase between teeth 14 and 16 had no detrimental influence on the adjacent or contralateral teeth.

Finally it should be emphasized that managing to reconstruct proximal contacts in clinical practice using the three-step matrix technique is a challenging and sophisticated job. The model situation that was used during the study facilitated the procedures significantly. Therefore, clinical results might not be as ideal as the results found within the study. Therefore, further investigations are necessary to test the feasibility of the technique in different clinical settings.

CONCLUSIONS

Within the limitations of this *in vitro* investigation it was shown that posterior direct-composite additions inserted with the three-step matrix technique formed well-contoured proximal contacts that were at least as tight as the original contacts.

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