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Research Article

Long-Term Effectiveness of Metal-Etched Splints and the Role of Patient Compliance During Supportive Periodontal Therapy

Jean-Nicolas Hasson[1]*, Emmanuel Brand[1], Léa Michaud[1], Dominique Fricker[1] and URS Brägger[2]

[1]*Private Practice, Mulhouse, France*

[2]*Department of Reconstructive Dentistry and Gerontology, University of Berne, Switzerland*

***Corresponding Author:** Jean-Nicolas Hasson, Private Practice, Mulhouse, France.

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Abstract

Background: Splinting of teeth has been progressively abandoned as treatment for periodontal disease due to a lack of evidence of improved clinical outcomes.

Objective: Our aim was to assess long-term effectiveness of metal-etched splints.

Material and Methods: Patients who received periodontal treatment involving a metal-etched splint, designed to reduce tooth mobility and/or migration, between 1985 and 1995 were recalled for clinical re-evaluations until 2014. Criteria assessed included supportive therapy frequency, plaque score, pocket depth, bone modification, patient-reported outcomes, and complications, such as debonding and caries.

Results: The initial group included 48 splints of 3–10 abutments each. Ultimately, 21 patients (22 splints) were followed up for 232 to 318 months. There was a relationship between supportive therapy frequency and plaque score improvement at the first recall ($P = 0.0005$), which decreased gradually with time (up to $P = 0.0404$). There was a correlation between plaque score and bone level modification by end of the study ($P = 0.0002$). Complications proved to be minimal.

Conclusion: These findings suggest that metal-etched splints may be used as an adjunctive treatment on periodontally compromised dentitions when followed up carefully and may be recommended for patients reluctant to undergo implant surgery under optimal conditions, such as a low local rate of caries.

Keywords: Periodontal diseases, patient compliance, supportive periodontal therapy, periodontal splints, long term care, resin bonded bridges

Introduction

Splints have been used since at least as early as 2500 BC [1]. Splinting aims to treat one of the effects of periodontal disease, namely tooth mobility, providing relief to the patient by restoring normal function. The disease itself is treated with other types of therapy. The common alternatives for stabilization of mobile teeth are removable appliances; however, these are ineffective because of their inability to immobilize teeth in the axial direction.

Fixed splints may be divided into two major categories: fixed partial dentures and splints based on different types of reinforced composite resins. Treatment with fixed partial dentures is an expensive procedure that requires a substantial amount of chair time [2,3]. Reinforced composite splints are implemented in many different ways, combining the bonding and esthetic characteristics of composite resins with the strength of metal components. Over the long term, these splints may increase dental plaque accumulation [4], the esthetics may deteriorate, and there may be mechanical failure of the composites, all of which complicate maintenance [5]. In summary, ongoing maintenance costs of these splints tend to override the initial low expense.

In 1973, Rochette [6] described a technique using composite material and a perforated cast-metal framework to splint mobile lower anterior teeth. The technique was eventually adapted by the author for use as a fixed partial prosthesis, and modified by etching the metal to replace initial perforations for retention. Maryland bridges were developed in the early 80s by Livaditis and Thompson [7]. The above retention techniques were developed for metal-etched bridgeworks and were also used for splinting [8]. Unfortunately, in the long run, they exhibited disappointing survival rates [9-11].

The purpose of this study was to describe a modified Rochette splinting technique and to assess its long-term effectiveness during supportive periodontal treatment. Furthermore, patient satisfaction and complications were reported.

Material and Methods

This study received approval from local ethical committee (CE-2020-183) Strasbourg, France. All investigations were carried out in accordance with the ethical guidelines of the "Declaration of Helsinki".

Subjects

A list of patients receiving treatment involving a metal-etched splint in one private practice between March 1985 and June 1995 was compiled. All cases selected for this study had their treatment performed by the same practitioner (J. N. Hasson) and dental technician (D. Fricker), using the same bonding material (Super-Bond® C and B, Sun Medical Co., Ltd., Moriyama, Japan) and metal framework (Ugirex II®, Ugin, Seyssins, France). Only patients diagnosed with chronic periodontitis were included in this study. None of the treated patients had a history of active periodontal treatment in the year preceding splinting, nor major contributing systemic conditions. After an initial comprehensive examination, the various treatment options, including splinting as an adjunct to periodontal therapy, were discussed with the patient before written consent was provided. We included only cases with splints that were designed to ensure that teeth were caries-free, required minimal restorations, and did not extend onto functioning occlusal surfaces. None of the included patients were scheduled for resective surgery.

Experimental design

Patients underwent an initial examination, where pocket depth and tooth mobility were assessed, and a complete set of periapical radiographs were taken. Splinting was performed by the end of the initial therapy session. Incisors and canines were not prepared before impression. Molars and premolars were prepared according to the principles in Simonsen., *et al*. [12]. An impression of the required splint was made on deposit-free surfaces with an alginate material (Zelgan®, De Trey-Dentsply Corp., Irvine, USA). Barricaid® (De Trey-Dentsply Corp.), a light-cured periodontal dressing, was placed on the interdental and facial aspects of the impression to immobilize teeth and avoid tearing while removing the impression from the mouth. The result was a two-part alginate impression (Figure 1a, b). Barricaid® has the advantage that it can be transferred to the adequate position in the impression (Figure 1c, d, e). Precautions were taken to avoid adding Barricaid® to any zone that would eventually be covered by the metal framework.

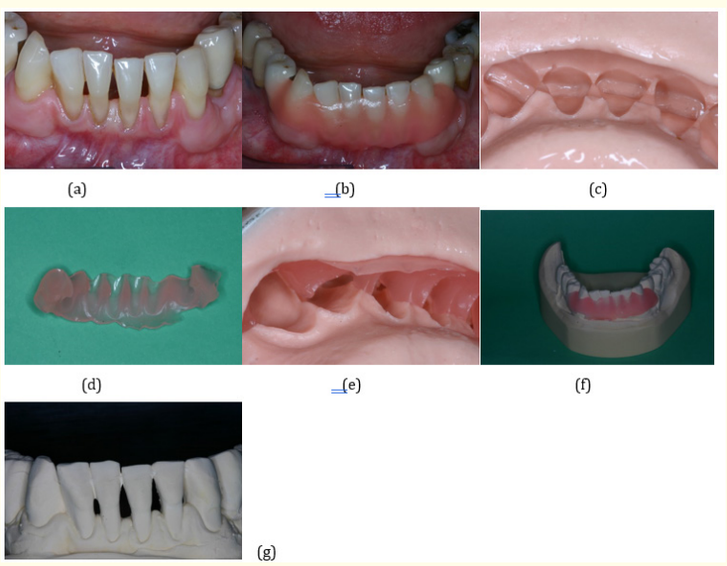

Figure 1: In order to achieve a reliable alginate impression, interdental spaces were covered with an additional material (Barricaid®) (a, b), which was eventually added to the impression material (c, d, e) to provide adequate dental contours in the casts (f, g).

Fuji-Rock II® (G. C. Corp., Tokyo, Japan) was poured into the impression within 15 minutes (Figure 1f, g). Frameworks were initially mounted in GC Pattern Resin® (G. C. Corp.), according to the method described by Simonsen., *et al*. [12]. (1983), and ultimately cast in Ugirex II®. Frameworks were assessed for fit in the patient's mouth. After sandblasting, the anode of the etching device (Mary Etch®, Krupp Medizintechnik, Essen, Germany) was connected to the framework. The lingual face of the framework was covered with adhesive wax (Abdeckwachs®, Krupp Medizintechnik) to prevent damage to its polished surface. Etching was performed in a Bondi-Etch® solution (Krupp Medizintechnik) for 8 min/cm^2 at 250 mA. The remaining wax was removed with steam to prepare the framework for the bonding procedure.

Teeth were carefully cleaned of plaque, calculus, and stains with scalers and an air-abrasive device (Plaque Sweep™ and PROPHYflex™ device and Prophyflex ™ Cleaning Powder, KaVo, Warthausen, Germany). Tooth surfaces were rinsed thoroughly to reduce the remaining sodium bicarbonate. A rubber dam was placed over the teeth without lubricant. An etching solution, consisting of a 37%

solution of phosphoric acid (Total Etch, Ivoclar, Schaan, Liechtenstein), was applied to the enamel for 45 s and thoroughly rinsed off with a water syringe. Surfaces were vacuum-dried to avoid oil contamination by dental equipment. Bonding material was applied at a low temperature (between 10°C and 14°C), according to manufacturer indications. Time spent on this step was minimized to maintain a glossy surface. The framework was firmly pressed against the teeth for 3 min, the rubber dam was gently removed, and the patient was instructed not to put any pressure on their teeth for a further 20 min. Excess bonding material was not removed before 20 min elapsed to avoid mobilization of the splint. Thereafter, positioning rests were removed at high speed using small diamond disks (825.314.023, Komet, Lemgo, Germany), and the splint was polished with an Arkansas stone bur and Vaseline® (Cooper, Melun, France), followed by a silicone bur. Any excess bonding material was removed at this time.

Criteria of assessment

Patients underwent reevaluation of their splints between June 1996 and September 1997 (reexamination #1), between February 2002 and April 2003 (reexamination #2), and between September 2011 and November 2014 (reexamination #3). To eliminate the bias of subjective assessment of the final result, measurements were taken by different operators for reexamination #1 and #2 (Emmanuel Brand [E.B.] and Léa Michaud [L.M.], respectively. Measurements for reexamination #3 were taken by E.B. Therefore, the inter-examiner probing depth could be assessed as a measure of reproducibility.

Dental parameters

Dental parameters assessed for reexamination #2 and #3 were

- Debonding of the framework and history of debonding as reported in individual case charts, as well as the remedy (splint reduction or rebonding by inlay); and
- Caries 2.3.2 Periodontal parameters
- Periodontal parameters, assessed at the initial examination and at all reexaminations, included
- Initial tooth mobility [13], assessed only at the initial examination, as no mobility could be determined after attachment of the splint.
- Supportive therapy frequency.
- Plaque score, where teeth were stained with a disclosing solution, the presence or absence of plaque on approximal, buccal, and lingual/palatal surfaces were assessed, and the percentage of plaque-coated units were calculated [14].
- Pocket depth was recorded with a CP-12 Hu-Friedy periodontal probe [13] and pockets were divided into three groups based on depth (≤3 mm, 4 or 5 mm, and ≥6 mm), as well as into three groups based on change in depth of ≥2 mm (improvement, stable, or degradation), as described by Badersten., *et al*. [15]; and
- Radiographic bone modifications, where, as radiographs were not standardized, measurements were adjusted by the ratio of the initial to the final measurement of tooth length (Figure 2). Periapical radiographs obtained at the initial examination and for reexamination #1 were digitized as described by Fourmousis., *et al*. [16]. Later radiographs were digital.

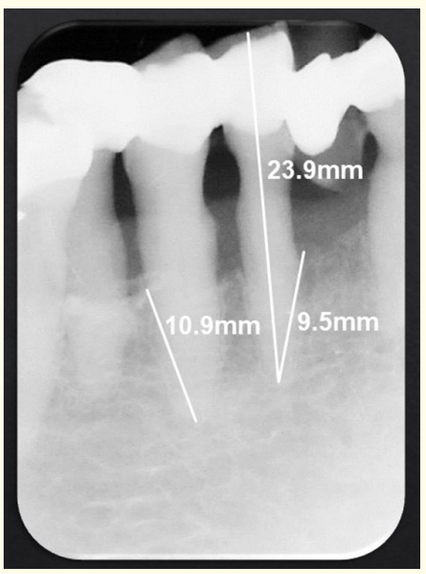

Figure 2: Bone level was assessed at the mesial and distal aspects of the tooth, and total tooth length was measured to adjust measurements on non-standardized radiographs.

Periodontal parameters were analyzed in relation to frequency of supportive therapy visits between initial examination and final reexamination. Three groups were designated:

- Group 1 consisted of patients who attended supportive therapy at least twice a year and were compliant throughout the study.
- Group 2 consisted of patients who attended an average of one to two supportive therapy appointments per year since the beginning of the study, some of whom were compliant and did not need more appointments, and some of whom were erratic in terms of compliance; and
- Group 3 consisted of non-compliant patients attending less than one appointment a year.-

Patient assessment

Patients that were examined at reexamination #1 were asked to discuss the following criteria

- Cost, where patients were asked to rate the expense of the splint on a 4-point scale.
- Adaptation to the splint, where patients were asked to rate how rapidly they adapted to the splint on a 4-point scale.
- General satisfaction, where patients assessed on a 4-point scale how well we took care of their problem; and

- Patient remarks, in terms of their observations concerning the splint.

Statistical analyses

All data are expressed as the mean and the standard deviation. Linear regression analysis was performed to determine the relationships between periodontal parameters and frequency of supportive periodontal therapy. Patients were defined as the statistical unit when pocket modification was being studied, and measurements were defined as the statistical unit when radiographic bone modification was being computed. Results were obtained by ANOVA table with differences considered significant for P-value < 0.05. One-way ANOVA was used to compare different groups of patients. When Gaussian distributions of values could not be verified, Kruskal-Wallis Test was performed.: All statistics were performed using GraphPad InStat version 3.00 for Windows 95 (GraphPad Software, San Diego, CA, USA; RRID:SCR_000306).

Results

For the initial assessment, we included 45 patients between 26 and 88 years of age. Indications for splinting included tooth mobility that interfered with normal function (95%), tooth migration due to periodontal disease (43%), and tooth loss due to extreme periodontal disease, followed by replacement with a pontic (27%).

Between initial and final assessment, 24 patients dropped out of the study, as follows

- Ten passed away (one had two splints).
- Four could not be reached.
- Three had their teeth extracted because of progressive periodontal disease.
- Two had teeth modified for prosthetic purposes (fixed bridgeworks).
- Two moved away.
- Two were medically handicapped and could not attend reexamination (one had two splints); and
- One refused to be reexamined.

The observed group at the end of the study was composed of 21 patients with 22 splints. These splints included 122 abutments (on average, 5.5 retainers per splint) and 8 pontics, and most of the splints (21/22) were located in the mandible. Details of the groups are described in Table 1. In terms of reproducibility, inter-examiner probing depth was identical 62.08% of the time, within 1 mm apart 97.71% of the time, and within 2 mm apart 99.43% of the time.

Dental parameters

Complications encountered with the 22 remaining splints are summarized in figure 3. The following was observed

- Four debondings (two due to caries; all four occurred between 134 and 266 months after bonding), resolved by shortening the splint, where one of the outer teeth debonded and the splint survived;
- One debonding on a lower premolar, restored by rebonding with an inlay;
- Two roots had to be extracted because of progressive periodontal disease, with the crown of each remaining attached to the splint (Figure 4); and
- Three caries: one tooth was treated and maintained in the splint despite initial decay, the other two were extracted and the splint reduced.
- In the 24 patients who could not be re-examined, six debondings were recorded, as follows:
- Four debondings on lower premolars due to an inadequate bonding surface, resolved by shortening the splint by one tooth, which was extracted; for cases treated after 1996, a tooth preparation modifying the shape into a cuspid-like tooth seemed successful, no debonding was recorded afterward; and
- Two debondings on lower incisors, rebonded successfully by inlays.

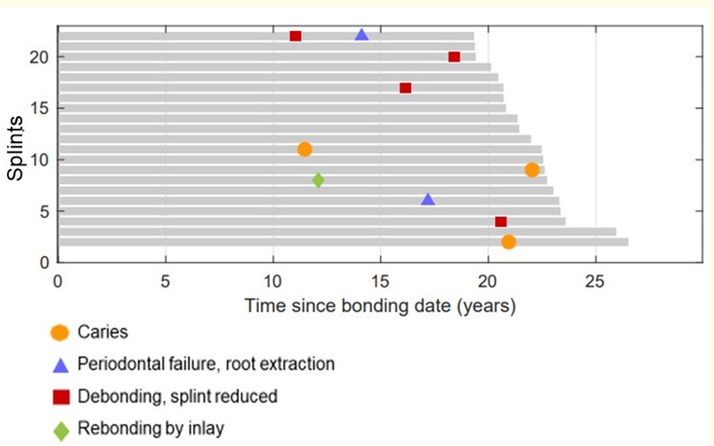

Figure 3: Overview of all complications and further interventions per splint over time (each horizontal grey bar represents a splint).

Figure 4: A splint, 20 years after bonding. The root of tooth 41 (⇩)was extracted due to progressive periodontal disease after 15 years of non-surgical therapy.

Periodontal parameters

All three patient-compliance groups (group#1 n = 7, group#2 n = 5, group#3 n = 9) were equivalent in terms of age, pocket depth, number of abutments, and appointment frequency at reexamination #1 (ANOVA, *P* = 0.9858). At reexamination #1, age was statistically significantly related to plaque score (*P* = 0.0122) and plaque score improvement (*P* = 0.0409). Pocket depth was substantially reduced in all patient-compliance groups; in fact, the number of pockets deeper than 4 mm dropped from 26.7% before, to 3.2% after initial periodontal therapy. Bone level modification did not correlate with plaque scores (*P* = 0.9359).

At reexamination #2, plaque scores of non-compliant patients demonstrated a noticeable increase, and a decrease in supportive therapy frequency correlated with a higher plaque score (r = -0.4627, *P* = 0.0301) (Figure 5). There was a positive correlation between plaque score and bone level modification (*P* = 0.0450).

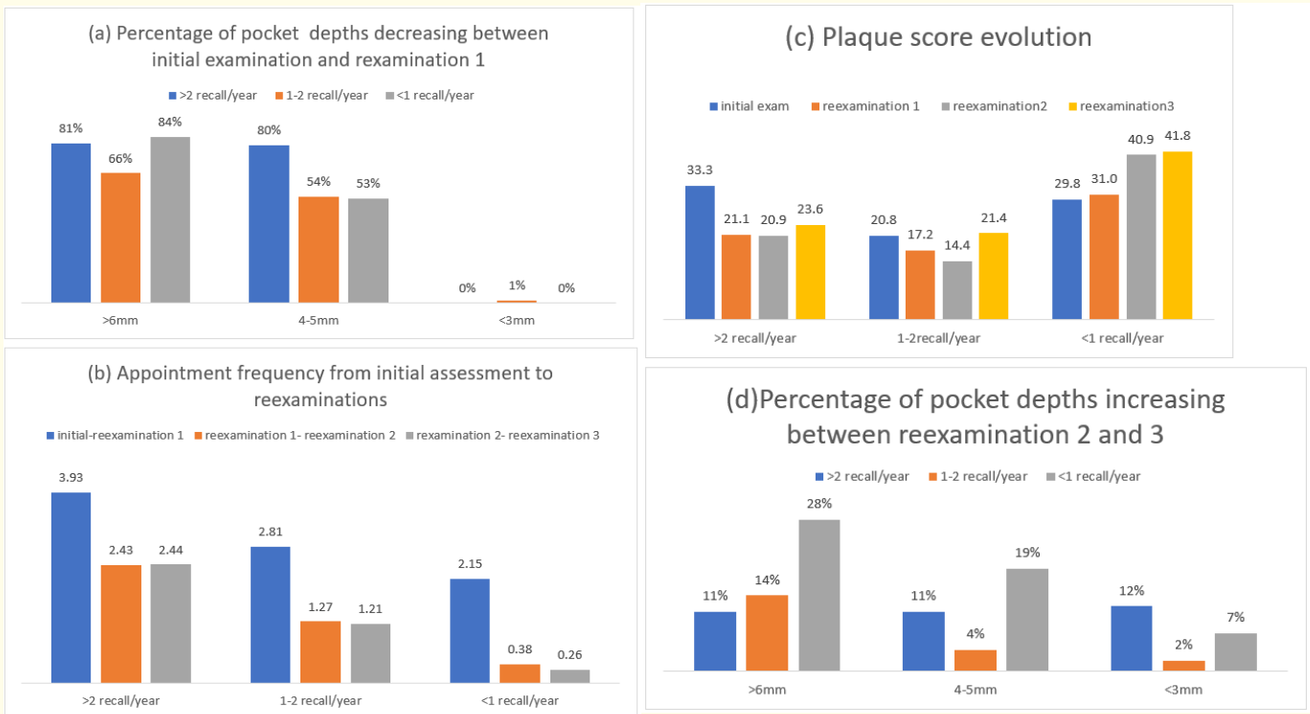

Figure 5: A recall is defined as non-surgical periodontal therapy that includes plaque elimination education. All patient-compliance groups demonstrated a noticeable improvement in pocket depth (a) after initial therapy. Patients that maintained a supportive therapy frequency more than once a year (b) maintained improved plaque elimination levels (c) and, for the most part, maintained pocket depth (a, d) throughout the study. Group 2 was composed of compliant patients who did not need more appointments, as well as erratic compliers; results were similar to those observed in Group 1. Non-compliant patients demonstrated a rapid decline in interest to receive ongoing periodontal supportive treatment (b) and experienced substantially greater periodontal breakdown over the long term (c, d). Plaque score was defined as the percentage of plaque-coated units.

At reexamination #3, bone-level increase was particularly notable at sites adjacent to tooth extractions (P < 0.01). When these sites were excluded, group 3 experienced substantial bone loss, principally in the incisor area (Figure 6), concomitant to continuous degradation of pocket depth (Figure 5). Groups 1 and 2 exhibited a stable bone level throughout the study. On the other hand, there was a statistically significant linear correlation between plaque score and bone level modification (P = 0.0002). The relationship between frequency of supportive therapy and plaque score was very significant at reexamination #1 (P = 0.0005) and decreased in significance at reexamination #2 (P = 0.0098) and #3 (P = 0.0404).

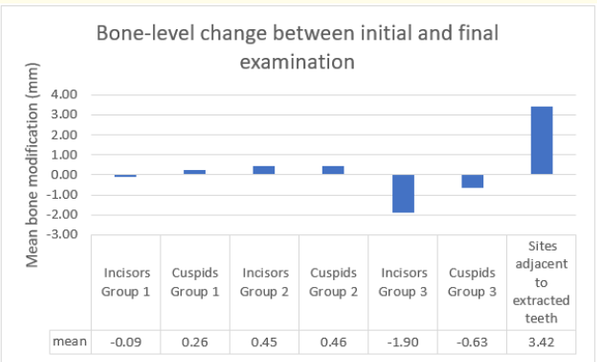

Figure 6: At final examination, sites adjacent to extracted teeth demonstrated significant bone gain compared to that at the initial measurement when compared to other sites (unpaired t-test, t = 4.801, P < 0.001). Most of the other sites exhibited minimal changes in bone level, except for bone loss at the incisors of group 3 non-compliant patients (unpaired t-test, t = 4.907, P < 0.0001).

Patient assessment

Adaptation to the splint

Of the 43 patients questioned at reexamination # 1, most adapted very rapidly (n = 17, 40%) or rapidly (n = 25, 58%) to the splint. Only one patient (2%) required a long time (two weeks) to adapt. Therefore, over contouring did not seem to cause much discomfort to most patients.

General satisfaction

Most patients (n = 34, 79%) were very satisfied and the others (n = 9, 21%) were satisfied with the procedure.

Cost

Twelve patients (28%) considered the technique inexpensive and 12 (28%) were neutral. Nineteen patients (44%) considered the procedure expensive, and none considered it very expensive.

Patient remarks

In addition to the previous responses, patients made the following points:

- Seven felt that more calculus accumulated once the splint was in place.
- Two indicated disapprovals with the grayish color of the incisal edge; and
- One noted a temporary metallic taste.

Discussion

After a mean follow-up of more than 20 years, approximately half of the initial group was available for examination. Therefore, in terms of patient age and dropout, our study is comparable to Axelsson., *et al.* study [17].

Cases in this study were treated in a very conservative manner. None of these patients exhibited a plaque score or bone loss indicating resective periodontal surgery. As demonstrated by Löe., *et al.* in 1986 [18], lower incisors exhibit a more pronounced loss of attachment than do canines and premolars, which have longer roots; the clinical root/crown ratio is considerably less favorable for mandibular incisors. As mandibular incisors and canines are less susceptible to decay than other teeth are [19], an acceptable bonding surface is more readily available for these teeth. The optimized treatment plan for retaining oral function is oriented toward long-term maintenance of lower premolars, cuspids, and incisors using a splint, and replacement of molars using dental implants, where warranted and possible [20]. This option is of particular use to patients with a high cumulative risk of implant loss or who are reluctant to undergo surgical procedures. Another advantage is that it more readily maintains dental esthetics, which is particularly challenging to achieve for mandibular incisors via implants.

Dental parameters

Our primary aim was to evaluate the long-term effectiveness of metal-etched splints in patients seeking therapy for advanced periodontal disease. The low rate of debonding in this study suggests that the technique we used is an effective supportive therapy to immobilize teeth over the long term. None of the bonded splints had to be totally removed over the entire study period because of the technique itself. Our study population had a mean age of 51.9

	Initial (SD)	Reexamination #1 (SD)	Reexamination #2 (SD)	Reexamination #3 (SD)
Number of patients observed	45	43	40	21
Sex (female/male)	26/19	26/17	23/17	12/9
Number of splints observed	48	46	42	22
Mean age at initial examination. (Standard Deviation)	51.9 (11.9)	52.2 (12.1)	52.8 (12.1)	49.5 (12.2)
Mean age at reexamination. (Standard Deviation)		53.9 (12.4)	62.8 (12.4)	71.5 (12.5)
Number of abutments	274	260	247	122
Number of abutments per splint	5.7 (1.3)	5.7 (1.3)	5.9 (1.2)	5.5 (0.9)
Mean observation time. (Standard Deviation)		52.8 (23.6)	114.4 (24.6)	262.3 (23.8)
Mean number of supportive therapy appointments (Standard Deviation)		7.0 (6.2)	12.7 (11.1)	29.0 (11.1)
Mean supportive therapy frequency per year from the initial examination (Standard Deviation)		2.0 (1.5)	1.3 (1.0)	1.4 (1.0)

Table 1: Patient characteristics at different periodontal therapy appointments.

years, which is much higher than that of the study by Creugers., *et al.* (1989; 30 years) [21] or that by Williams., *et al.* (1989; 35.4 years) [22]. Bite force in older patients is statistically significantly lower than in younger patients, as revealed by Helkimo., *et al.* [23]. In addition, periodontally involved teeth are much easier to manage in the mandibular anterior area in terms of bonding, as the crown is totally exposed, and the use of a rubber dam is much simplified by root exposure. Last, it has to be observed that the technique used in the present study was applied by an experienced dentist-technician team; all cases treated during the initial learning period or by any modification of the technique were excluded from the study. In comparison, the Dunne and Millar study [10] was performed in a teaching hospital, and all resin-bonded prostheses were performed by undergraduate students, house officers, and teaching staff, with various degrees of experience with the technique.

Improvements in bonding results observed in the current study may be due to the particular modifications we made to the technique. The use of alginate as impression material may play a role: the elasticity of the material allows the practitioner to obtain an impression on hypermobile teeth without inadvertent tooth displacement or extraction. When tooth extraction is planned, it can be performed immediately prior to splint insertion. Further, the use of Barricaid® allows the practitioner to obtain a two-part impression without tearing the alginate, while maintaining tooth position. When extensive splinting is performed, the impression has to be precise at the single-tooth scale, and individual teeth are maintained in place by positioning hooks during bonding.

The low level of decay observed in our study is probably related to the low incidence of caries in the surrounding area in patients who did not exhibit any major deterioration at the initiation of the study, as well as the effectiveness of supportive therapy provided.

Periodontal parameters

The Global Plaque score was used in this study because the authors believe that plaque reexamination is a key element in the success of the treatment, and it can be performed, eventually improved by the patient. Pocket depth and radiographic bone modifications depend on the quality of plaque reexamination.

The relationship between supportive therapy frequency, plaque score improvement, and pocket depth reduction was very high at first recall, but decreased gradually over approximately 20 years. This may be due to decreased plaque reexamination with an increase in age.

A correlation was observed by the end of the study between plaque score and periodontal breakdown. It is interesting to observe that there was an improvement over the short term in pocket depth in non-compliant patients despite poor plaque reexamination, which may be attributed to initial therapy. The correlation between plaque reexamination and bone level modification became prominent only at reexamination #3. The fact that the group of compliant patients did not exhibit a better result at the end of the study is probably related to the fact that ageing patients have a hard time to keep an adequate plaque reexamination.

A noticeable improvement in periodontal parameters was observed at sites adjacent to extractions. Degradation of bone level was more prominent at incisors, contributing to the early loss of these teeth.

Patient assessment

Over 97% of the patients felt comfortable to very comfortable after the splinting procedure.

There were only a few negative comments in terms of esthetics. This is probably due to lingual location of the metal framework, as well as the age group of patients typically being less concerned with esthetics.

A substantial cost reduction was obtained by using metal-etched splints, when compared to cemented fixed partial dentures or implant-supported prostheses. This allowed us to treat patients that would not be able to afford these more expensive options and were not ready for removable dentures. The reason why half of the patients considered this procedure expensive is probably related to the fact that dentistry is thought to be expensive in general.

In conclusion, the present findings suggest that metal-etched splints may be used as an adjunctive treatment on periodontally compromised dentitions when followed up carefully and may be recommended for patients reluctant to undergo implant surgery under optimal conditions, such as a low caries rate in the local population.

It has to be kept in mind that this study is limited by the fact that the treatment was provided by a very experienced dentist-technician team. Moreover their learning period between 1983 and 1985 was excluded from the present results. Future studies should also incorporate less experienced dentists and technicians, so that the generalizability of our results can be verified.

Based on the present results, it can be summarized that metal-etched splints

- Effectively and instantly restores dental function when teeth are compromised by periodontal disease.
- Can be adequately fabricated from two-part alginate impressions.
- Require no tooth preparation for anterior teeth.
- Have a clinically acceptable long-term survival rate without debonding.
- Are generally experienced as providing minimum discomfort.

And that a better prognosis is obtained for sites with deep pockets by an increased frequency of supportive therapy.

Recent advances in dentistry have made it possible to replace two-part impressions with digital impressions, to a satisfactory degree. Further research is needed to provide a metal free splinting material that can improve esthetic results while possessing a similar thickness and comparable long-term outcomes.

Clinical Relevance

- **Scientific rationale for study:** The long-term effectiveness of metal-etched splints in immobilizing teeth as a supportive periodontal treatment is unknown. It may be of particular use to patients with a high cumulative risk of implant loss or who are reluctant to undergo surgery.
- **Principal findings:** There was a relationship between supportive therapy frequency and plaque score improvement, and between plaque score and periodontal breakdown. Complications were minimal.
- **Practical implications:** This technique may be used for the effective immobilization of periodontally involved dentition, particularly for patients who cannot afford more expensive options, or who want to avoid implants.

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