To Splint or Not to Splint: The Current Status of Periodontal Splinting

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Abstract

Loss of tooth-supporting structures results in tooth mobility. Increased tooth mobility adversely affects function, aesthetics, and the patient's comfort. Splints are used to overcome all these problems. When faced with the dilemma of how to manage periodontally compromised teeth, splinting of mobile teeth to stronger adjacent teeth is a viable option. This prolongs the life expectancy of loose teeth, gives stability for the periodontium to reattach, and improves comfort, function and aesthetics. Although splinting has been used since ancient times, it has been a topic of controversy because of its ill effects on oral health, including poor oral hygiene and adverse effects on supporting teeth. There have been considerable advancements in the materials used for splinting, resulting in fewer ill effects. This article is intended to provide the clinicians with an updated overview of splinting, types and classification of splints, with their indications, contraindications, rationale and effects on oral health.

Keywords: Splints, periodontally compromised teeth, bone loss, periodontitis, tooth mobility

Introduction

Periodontal disease is characterized by gingival inflammation, loss of connective tissue attachment and destruction of alveolar bone. Progressive attachment loss around the involved teeth eventually results in increased mobility. (Ericsson *et al.*, 1993). Hypermobility of teeth is a common sequel following the loss of tooth-supporting structures, which may be due to various etiological factors such as periodontitis, improper occlusal forces, etc.

Increased tooth mobility adversely affects function, aesthetics, and the patient's comfort. Clinical management of periodontally compromised teeth with advanced mobility remains a challenge to the clinician. Hence, splints are being used to overcome these problems. Splinting teeth to each other allows distribution of forces from mobile teeth to their immobile neighbours, thereby gaining support from stronger teeth. This prolongs the life expectancy of the loose teeth, gives stability for the periodontium to reattach, and improves comfort, function and aesthetics.

Literature indicates that the main reasons for periodontal splinting are primary and secondary occlusal trauma, and progressive mobility, migration/drifting due to periodontal and/or periapical causes (Tarnow and Fletcher, 1996). Tooth splinting may be indicated for individual mobile teeth as well as for the entire dentition in more extreme situations, where

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extraction and implant or removable partial denture therapy are not viable alternative treatment options, because of patient- and site-related factors. It is an accepted practice to splint mobile teeth, particularly lower incisors, to maintain the patient's natural dentition as long as possible (Quirynen *et al*., 1999). Tarnow and Fletcher (1996) described the indications and contraindications for splinting periodontally involved teeth. They stated that the rationale for splinting teeth should include the severity of periodontal disease as determined by the amount of radiographic bone loss and/or the measured tooth mobility.

Tooth mobility and its causes

Teeth exhibit a certain degree of mobility known as physiologic tooth mobility. Tooth mobility secondary to inflammation of the periodontium and bone loss is considered as pathologic (Pollack, 1999). Mobility is assessed as the amplitude of crown displacement resulting from the application of a defined force (Muhlemann, 1954). The magnitude of this amplitude has been used to distinguish between physiological and pathological tooth mobility. Two basic factors determining the degrees of tooth mobility are the height of the supporting tissues and the width of the periodontal ligament.

Periodontal destruction often leads to tooth hypermobility, secondary to bone loss. The presence of traumatic occlusion that results in the jiggling forces can lead to further periodontal destruction (Dombret and Marcos, 1989).

When patients present with periodontal disease and mobile teeth, efforts should be directed at resolving the periodontal disease before considering occlusal management, if the teeth are to be preserved. In the absence of periodontal disease, the most likely cause of tooth mobility is primary occlusal trauma. Rare causes of tooth mobility, such as abnormal, iatrogenically shortened roots following apical surgery/apicoectomy, excessive loading during orthodontic movement, root resorption or intrabony pathology, should also be considered (Bernal *et al*., 2002).

Tooth mobility and occlusion

Occlusal trauma/trauma from occlusion is described as trauma to the periodontium from functional or parafunctional forces causing damage to the attachment apparatus of the periodontium by exceeding its adaptive and reparative capacities (Gher, 1996). Generally, two forms of occlusal trauma are recognized:

1. Primary occlusal trauma: When the occlusal forces exceed the adaptive capacity of the healthy teeth, trauma results (Carranza, 1996).
2. Secondary occlusal trauma: Reduced ability of the tissues (periodontitis) to resist the occlusal forces (Carranza, 1996).

These forces can either be acute (an abrupt change in the occlusal forces) or chronic (gradual change). According to Glickman's concept, occlusal trauma together with plaque-induced inflammation act as co-destructive forces resulting in an alteration of the normal pathway of inflammation and the formation of angular bony defects and infrabony pockets (Glickman and Smulow, 1965).

In contrast to the co-destructive theory, Waerhaug (1979) believed there was no proof that occlusal trauma caused or acted as a cofactor in the formation of angular defects. He believed that infrabony pockets were associated with the advancing "plaque front" or apical growth of subgingival plaque and the formation of either horizontal or angular bone defects were dependent on the width of the interproximal bone. This bone loss, in turn, results in increased tooth mobility (Waerhaug, 1979).

How to evaluate tooth mobility?

S. C. Miller in 1950 developed the most commonly used clinical method of detecting tooth mobility. Using his method the tooth is held firmly between two instruments and moved back and forth and mobility scored on a scale of 0-3. A score of 0 denotes no detectable mobility when force is applied other than what is considered normal (physiological) mobility. A score of 1 indicates mobility greater than normal (physiological). Mobility up to 1 mm in a buccolingual direction is scored as 2. Mobility greater than 1 mm in a buccolingual direction combined with the ability to depress the tooth is scored as 3. Various invasive and non- invasive methods have been developed to detect pathological tooth mobility. Although invasive methods give a relatively accurate value non-invasive methods are accepted and preferred. A few of the most widely used non-invasive instruments are Periotest (Schulte and Lucas 1992), Periodontometer (Muhlemann 1955), and Mobilometer (http://www.google.co.in/patents/US2574715).

Decision-making in the splinting of mobile teeth

Tooth mobility can be reduced by occlusal adjustment and/or splinting. For selection of the treatment modality, the reasons for increased tooth mobility must be recognized - whether the cause is a widened periodontal ligament due to periodontal disease/trauma from occlusion, reduced height of the supporting tissues, or a combination of these factors.

Increase in mobility because of widened periodontal ligament may be reduced by occlusal adjustment alone by eliminating the occlusal interferences. In cases where occlusal adjustment will not reduce the tooth mobility, reduction of mobility can only be achieved by a splint. Splinting in such situations is only indicated if the mobility disturbs the patient's masticatory function or chewing comfort or aesthetics. If the increased mobility is due to a combination of widened periodontal ligament and reduced periodontal support height (without active periodontal disease), the occlusal adjustment may be sufficient to reduce the mobility to an acceptable degree.

However, splinting is to be considered if the patient's subjective chewing comfort is still disturbed (Nyman and Lang, 1994).

In the past, the use of splinting of periodontally compromised teeth was contentious. The presumption was that the use of splints to control tooth mobility was required to control gingivitis, periodontitis, and pocket formation. It was assumed that mobility had a direct relationship to attachment loss and vertical osseous defect formation. Another assumption was that increasing tooth mobility was a direct consequence of traumatic occlusion, bruxism, and clenching. Consensus also pointed to the fact that even normal physiologic functions including mastication and swallowing contributed to tooth mobility (Waerhaug, 1969).

A number of periodontal clinical trials investigated these assumptions. When teeth were occlusally overloaded and other variables that contribute to periodontal disease were controlled, it was difficult to produce gingivitis, periodontitis, or pocket formation (Bhaskar and Orban, 1955; Ramfjord and Kohler, 1959).

In another study, it was reported that there is no correlation between splinting and reduced tooth mobility during initial periodontal therapy (Kegel *et al*., 1979). Control of tooth mobility with splinting after osseous surgery did not reduce mobility of the individual teeth (Kegel *et al*., 1979). However, other studies report that tooth mobility can be controlled and managed with splinting and will improve periodontal prognosis. (Pollack, 1999; Laudenbach *et al*., 1977; Amsterdam, 1974). With such conflicting data, it is very difficult for the clinician to decide whether to use splinting or not, what degree of mobility can be managed, whether grade III mobility can be managed with splinting, or extraction is the ultimate cure. In this review we have tried to use our clinical experience to answer these questions to make it easier for clinicians to decide.

Currently, it is accepted that tooth mobility is an important clinical parameter in predicting periodontal prognosis. Splinting periodontally affected teeth helps in faster healing and regeneration. (Kathariya *et al*., unpublished data). We firmly believe that splinting of mobile teeth assists in regeneration of periodontal health, and improves function, comfort, and aesthetics. There is no doubt that splinting does reduce tooth mobility while the splint is in place (Serio, 1999; McGuire and Nunn, 1996). Further, regenerative procedures using membranes and bone graft have greater predictability if tooth movement is eliminated (Cortellini *et al*. 2001).

With the latest advances in splinting materials and a wide variety available, it becomes imperative to classify them. The clinicians should be able to segregate and identify splints, so that they can make the best use of them in various clinical circumstances. While the splint is in place it might cause difficulty in performing oral hygiene and attract more plaque accumulation, but with the advent of newer oral hygiene and interdental cleaning aids, this drawback can easily be overcome.

Selecting abutment teeth for splinting

While selecting an abutment tooth for splinting one should always consider the pericemental area of an abutment tooth. Ante (1926) postulated that "The total periodontal membrane area of the abutment teeth must equal or exceed that of the teeth to be replaced." Also, "The length of the periodontal membrane attachment of an abutment tooth should be at least one-half or two-thirds of that of its normal root attachment." Moreover, teeth with mobility/widened periodontal ligament should be avoided as abutments for splinting (Tylman and Tylman, 1960; Tylman and Malone, 1978)

Splint

According to the glossary of prosthodontic terms, a splint is defined as "a rigid or flexible device that maintains in position a displaced or movable part." The active term of splinting in dentistry is defined as the joining of two or more teeth into a rigid unit by means of fixed or removable restorations or devices (Glossary of Prosthodontic Terms, 1994). A splint has also been defined as any apparatus, appliance, or device employed to prevent motion or displacement of fractured or movable parts (Hallmon *et al*., 1996).

The biological rationale for splinting was elaborately discussed by Nyman and Lang in 1994 (Nyman and Lang, 1994)

Clinical rationale for splinting (Pollack, 1999; Serio, 1999; Siegel *et al*., 1999; Ramfjord and Ash, 1981; Lemmerman, 1976):

- To control parafunctional or bruxing forces.
- Stabilization of mobile teeth during surgical, especially regenerative, therapy. Friedman believed that unless splinted, mobile teeth may not respond as well to reattachment procedures (Friedman, 1953; Ferencz, 1987).
- Stabilization of a periodontally compromised tooth when more definitive treatment is not possible.
- Prevention of the supra-eruption of an unopposed tooth to eliminate the potential for the development of periodontal problems (Hirschfield, 1937).
- Stabilization of loose teeth to restore the patient's psychological and physical well-being.
- Splinting during or following periodontal therapy is useful and beneficial for controlling the effects of secondary trauma from occlusion. Also, it improves the patient's comfort and function (Ferencz, 1987).

Table 1. Classification of splints

Type	Details	Usage	Recommendation
Short-term temporary splint	Worn for < 6 months	During active periodontal treatment; may or may not lead to another type of splinting	Recommended
Medium-term provisional splint	For months to several years	For diagnostic purposes; usually lead to more permanent types of stabilization	Recommended
Long-term permanent splint	Maintain long-term stability	Worn indefinitely and may be either removable or fixed type (Lemmerman, 1976)	Recommended
External splints	E.g., ligature wires; night guards; interim fixed prostheses	**Ligature wire** Used for mobile anterior teeth E.g., Dead-soft round stainless steel wires (0.25-0.30 mm) or brass wires	Recommended
		Night guards: Recommended in patients with history of bruxism and clenching Stabilize teeth following selective occlusal adjustment Heat polymerized poly (methyl methacrylate) occlusal splint is commonly used (Mikami,1977)	Recommended
		Interim fixed prostheses: Used in periodontally compromised teeth until a definitive treatment plan is made. Restores esthetics and restores occlusal scheme to incorporate a definitive prosthesis in future. Added advantage is it provides time for evaluation of design and occlusal form before deciding to proceed with definitive restoration (Malone and Koth, 8th ed)	
	Composite resin restorative material with or without wire or fiber inserts	Composite resin restorative materials Increasing the bond strength of composite to enamel as well as dentine has led clinicians to attempt splinting of very mobile teeth. Preferred in splinting of anterior teeth for esthetic reasons. In order to enhance the shear stress, the composite is reinforced with high strength, bondable, biocompatible, aesthetic color and easily manipulated neutral fiber.	Recommended
Internal splints	Composite or fiber-reinforced composite material used as internal splints	Referred to as intra-coronal splints. Composite resin restorations can be placed in adjoining teeth and cured to eliminate any interproximal separation Can be further reinforced with metal wires, glass-reinforced fibers or pin. (Barzilay, 2000)	Not recommended

- The main objective and rationale of splinting and occlusal adjustments are to control the progressive tooth mobility (Lindhe and Nyman, 1977).

Indications for splinting (Belikova and Petrushanko, 2013; Lemmerman, 1976):

- Restore patients' masticatory function and comfort
- Stabilize teeth with increasing mobility that have not responded to occlusal adjustment and periodontal treatment
- Facilitate periodontal instrumentation and occlusal adjustment of extremely mobile teeth
- Prevent tipping or drifting of teeth and extrusion of unopposed teeth
- Stabilize teeth, when indicated, following orthodontic movement
- Create adequate occlusal stability when replacing missing teeth
- Stabilize teeth following acute trauma

Contraindications:

- Occlusal stability and optimal periodontal conditions cannot be obtained (Nyman and Lang, 1994)
- Poor oral hygiene
- Insufficient number of non-mobile teeth to adequately stabilize mobile teeth
- Presence of occlusal interference
- High caries activity
- Overall poor prognosis
- Crowding and malaligned teeth that may compromise the utility of splint

Principles to be followed while fabricating splint:

Should be simple in design without involving extensive tooth preparation

- Should be stable and efficient, easily repaired
- Should permit good plaque control
- Should not hamper periodontal instrumentation
- Should be non-irritating to the tissues
- Should be esthetically acceptable
- For every mobile tooth, at least two firm teeth should be present

Types of dental splints (Table 1):

Depending on the duration of use, splints are classified as temporary, provisional or permanent and may be either fixed or removable (Hallmon *et al*., 1996). Occlusal splints can be classified as provisional or definitive depending on the type of materials used and the intended duration the splint will be in place for (Ferencz, 1987).

Short-term temporary splint:

Temporary splints are worn for less than 6 months and may not be followed by additional splint therapy.

Medium-term provisional splint:

Provisional splints are used for months to several years with a definitive end to the splint therapy.

Long-term permanent splint:

Permanent splint maintains long-term stability.

Provisional splints:

As the name indicates, the objective of a provisional splint is to absorb occlusal forces and stabilize the teeth for a limited amount of time. They can be useful adjuncts to many different types of treatment (Chacker and Serota, 1966). They can be placed either externally or internally. External splints typically are fabricated using ligature wires, nightguards, interim fixed prostheses, and composite resin restorative materials. Internal splints, on the other hand, are fabricated using composite resin restorative material with or without wire or fiber inserts. Most provisional splints are made using some form of external support in their design (Malone *et al*., 1989).

Extra-coronal splinting

The simplest way to connect teeth to each other is the classic bonding method. The enamel surface of the tooth is etched, most commonly with 37% phosphoric acid. Composite resin can then be bonded to the etched surface and used to rigidly connect the teeth to each other (*Figure 1*). The composite resin splint can be strengthened by adding fibers to the splint or by using a fiber meshwork, e.g., Ribbond (Ribbond Inc., Seattle, WA, USA) to reinforce the material (*Figure 2*). Extracoronal resin-bonded retainers, which can be fabricated in a dental laboratory, serve to strengthen the overall bonded situation. The splints are usually cast from metals (*Figure 3*), usually non-noble alloys that can be electrolytically or chemically etched. Recent innovations in materials allow these frameworks to be air abraded and then cemented in place with adhesive resin cement (Barzilay, 2000). There are various materials used for extra-coronal splinting such as stainless steel wires (most commonly used), fiber reinforced composite (*Figure 4*), composite alone (*Figure 1*), and cast splints (*Figure 3*). Adjoining crowns, bridges, adjoining onlay preparations, and veneers without involving any internal line angles are part of extra-coronal splints. These adjoining prostheses can be laboratory fabricated, solder joined or precision attached. Extra-coronal splinting methods that attract more plaque, complicate oral hygiene and further compromise esthetics are obsolete and are to be avoided.

Reinforced splint:

Attempts have been made to embed wire, pins, nylon, stainless steel mesh, etc., with restorative resin. The inherent problem with these materials is the inability to chemically integrate with composite. This has led to research to develop an appropriate material that can overcome the drawbacks of previous materials. The challenge to place a thin but strong composite-based splint has been met with the introduction of a high-strength, bondable, biocompatible, esthetic and easily manipulated color neutral fiber that can be embedded in the resin structure (*Figure 4*). The added advantage is that this fiber also binds chemically with resin structure.

A variety of reinforcement fibers are available for use with composite for the purpose of splinting (*Table* 2): Splint It® (Pentron Clinical Technologies, LLC) – Open weave glass fiber ribbon, Ribbond®-Ribbon (*Figure 1*), Ribbond Lock-stitched, woven polyethylene ribbon, Interlig® Fiber-splint - open weave glass fiber ribbon [Angelus Industria de Produtos Odontologicos S/A Londrina-PR, Brazil], etc., in different widths and sizes of braided rope, woven or unidirectional fibers.

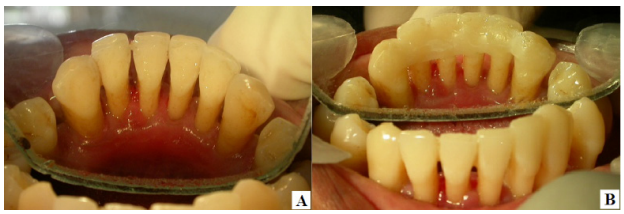

Figure 1: Extracoronal resin (Composite) bonded splint: [A] Pre-operative, [B] Post-operative Ribbond splint

Figure 2: Extracoronal resin (Composite) bonded retainers: Cast metal splint

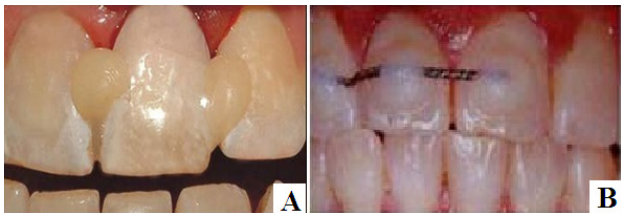

Figure 3: Obsolete extracoronal splinting [A] Composite interlocking splint, [B] Labial stainless steel wire splint

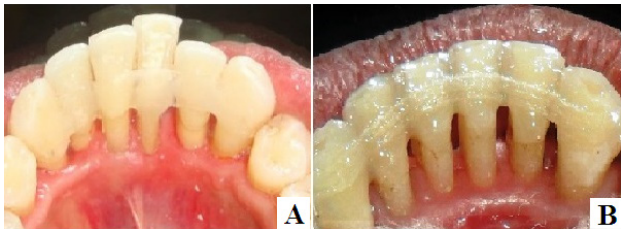

Figure 4: Extracoronal high strength, bondable, biocompatible, aesthetic and easily manipulated, color neutral fiber splint

New fiber-reinforced composite material Ribbond is basically a reinforced ribbon which is made from ultrahigh molecular weight polyethylene fiber having an ultrahigh modulus. Ribbond appears to be an adequate and easy method for splinting teeth. The various advantages of this material include: ease of adaptation to dental contours and ease of manipulation during the bonding process. Because it is a relatively easy and fast technique, no laboratory work is needed. It also has acceptable strength because of good integration of fibers with the composite resin; this leads to good clinical longevity. In addition, in the case of fracture during wear, the splint can be easily repaired. There is no need for removal of significant tooth structure, making the technique reversible and conservative. It also meets the patients' aesthetic expectations. Ribbond is an easy and good method for splinting and stabilizing teeth (Yildirim *et al.*, 2006).

Unidirectional pre-impregnated glass fibers (Serio, 1999; Giordano, 2000; Vallittu, 1998; Schmid *et al.*, 1979):

Glass fibers, in contrast with polyethylene fibers, have to be protected from environmental damage if they are to successfully function.

- These materials are esthetic, have translucency similar to castable glass-ceramics such as OPC and Empress.
- These fiber-reinforced resins are somewhat different than classical composites. Polishing of the restoration can be accomplished using diamond- or alumina-impregnated rubber wheels followed by diamond paste.
- The glass fibers can pose a health risk. They are small enough to be inhaled and deposited in the lungs, resulting in a silicosis-type problem. Therefore, if fibers are exposed and ground, it is extremely important to use a rubber dam for the patients and to wear a mask for the clinicians.
- Fibers can be a skin irritant, so gloves should be worn.
- If the fibers become exposed intraorally, they can cause gingival inflammation and may attract plaque. The fibers should be covered with additional composite resin. If this cannot be accomplished, the restoration should be replaced.

Open weave glass fibers (Serio, 1999; Giordano, 2000; Vallittu, 1998; Schmid *et al.*, 1979):

This open weave pattern has an inherent ability to dissipate stresses and prevent crack propagation which is not seen with the unidirectional glass fibers. There are no differences in shear bond strength (SBS) with the addition of fiber-reinforced composites (FRC) compared to composite without FRC, with the exception of the Connect product (Kerr, Orange, CA), which provided higher SBS values (Meiers *et al.*, 2003). Under flexural loading unreinforced and unidirectional pre-impregnated reinforced dental composites will fail in a brittle fashion, whereas the braid and leno-weave reinforced materials undergo deformation without rupturing.

The functionality of fiber-reinforced material

There are two basic properties by which fibers can enhance the efficacy of a composite splint. Fiber acts as a stress-bearing component. It will enhance the effect of the otherwise brittle matrix composite material. Secondly, it has a crack stopping or a crack deflecting mechanism, which in turn increases the toughness of the material.

Table 2. Types, trade name and material composition with the advantages and disadvantages of different types of splints

Type	Trade name	Material details
Fiber reinforced composite splint	Splint-It®-Pentron	Fiber splints are available in three unique designs for a variety of stabilization and reinforcement procedures The high strength glass and polyethylene fibers are pre-impregnated with a special resin ensuring complete saturation within each strand and eliminating the need to apply bonding agent The resin-treated fibers provide versatility, in addition to substantial strength and ease of placement **Unidirectional fiber strip:** The 3 mm wide unidirectional glass fiber strip is ideal for stabilizing mobile teeth, repairing dentures, and reinforcing temporary bridges **Woven fiber strip:** The 2 mm wide woven glass fiber strip easily tucks into interproximal contacts, adapts effortlessly to malaligned teeth, and stays in place due to its lack of memory **Braided rope strip:** The 1 mm wide braided polyethylene rope is ideal for use when lingual space is limited, and may also be used as a post
	Open weave glass fiber ribbon	Have been adapted to compensate for the unique structural design of periodontal splints Has an inherent ability to dissipate stresses and prevent crack propagation, which is not seen with the unidirectional glass fibers (Giordano, 2000; Vallittu, 1998)
	Ribbond (Eminkahyagil, 2006; Clinical Research Associates, 1997)	Advantages of this material include ease of manipulation and adaptation to dental contours during the bonding process, as it is a relatively easy and fast technique (no laboratory work is needed) In the case of fracture, the appliance can be easily repaired Now also available as thinner higher modulus (THM) Ribbond. This material is thinner than the regular Ribbond and has higher flexural strength. Its thinness allows the operator to adapt it more closely to the teeth. Developed by Dr. David Rudo Woven using spectra polyethylene fibers in a leno weave configuration It is lock stitched and cross-linked
Unidirectional pre-impegrated glass fibers	E.g., Prepreg (Giordano, 2000; Vallittu, 1998)	Unidirectional fibers oriented in multiaxial plane (e.g., 0°, +45°, -45°) stitched together Glass fiber reinforcing materials are available as resin-impregnated (pre-preg), fiber-reinforced glass fibers, in contrast with polyethylene fibers, and have to be protected from environmental damage These materials are esthetic and have translucency similar to castable glass-ceramics such as OPC and Empress The glass fibers can pose a health risk. They are small enough to be inhaled and deposited in the lungs, resulting in a silicosis-type problem.
Open weave glass fibers	(Giordano, 2000; Vallittu, 1998)	Can be used with both polyester and epoxy resins Open weave glass fiber design has been adapted to compensate for the unique structural design of periodontal splints Has an inherent ability to dissipate stresses and prevent crack propagation, which is not seen with unidirectional glass fibers
Provisional fixed partial prosthetic splint	Heat processed acrylic resin splint (Renggli and Schweizer, 1994; Pollack, 1999)	In certain situations occlusal rehabilitation is complex in nature. In such situations, provisional prosthetic splints play greater role Allows patient and periodontist to evaluate restorative treatment planning Material of choice to fabricate a provisional splint is heat processed acrylic resin
Definitive fixed partial prosthetic splint	Crown and bridge prosthesis (Renggi, 1984; Seigel, 1999)	Serve additional purpose of splinting the abutment and other supporting teeth Conventional crown and bridge prostheses fulfill this requirement very well if adequate abutment teeth are included Optional resin-bonded splint can be designed if anatomy and situation of the teeth are not conducive to slender cement retained prosthesis

It is important for the clinician to fabricate a splint that is able to resist all these failure mechanisms in the best possible fashion. All these failure mechanisms depend on the direction in which loads are applied to the splints (Giancotti *et al.*, 2005).

Intra-coronal splinting

Intracoronal methods are also available. Composite resin restorations can be placed in adjoining teeth and cured to eliminate any interproximal separation. These restorations can be further reinforced with metal wires, glass-reinforced fibers or pins. If a crown or bridge involves internal line angles they are to be classified as intra-coronal splints. If restoration of the mouth includes adjoining crowns (involving internal line angles), adjoining inlay preparation or adjoining crown and inlays, the crowns and/or inlays can be splinted to each other by solder joints or precision attachments. The use of attachments affords the practitioner the ease of preparing nonparallel abutments yet achieves a splinted result (Yildirim *et al.*, 2006). Intra-coronal splints that require extensive tooth cutting are outdated and are not recommended.

Removable and fixed prostheses

When one or two teeth are missing or have to be removed because they have a poor prognosis, a decision has to be made about the question of replacement of the missing teeth as well as stabilizing the remaining teeth. There have been controversies about the use of periodontally compromised teeth as abutment teeth. Several studies accepted such teeth as abutments if favorable crown:root ratios were available or generated by addition of another abutment tooth (Nyman and Lindhe, 1976; Yildirim *et al.*, 2006). If the crown:root ratio of a periodontally compromised tooth is not favorable, a decision can be made to extract that tooth. The extracted tooth can then be used as a natural tooth pontic after extra-oral root canal and splinting with the adjacent teeth (*Figure 5*; Baydaş and Denizoğlu, 2006).

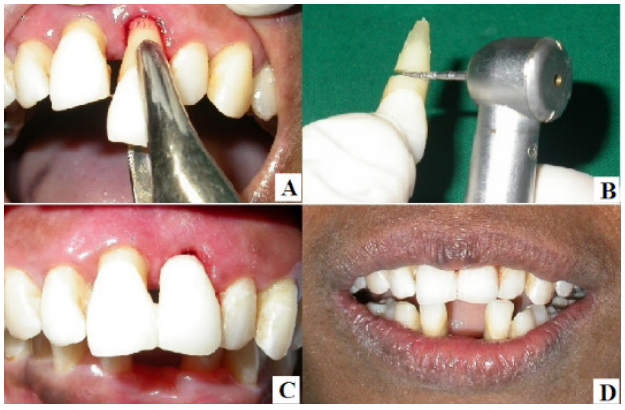

Figure 5: Natural tooth pontic splint: [A] Extraction of a periodontally compromised teeth with unfavorable crown:root ratio, [B] Intentional extra oral root canal treatment and reduction of the extracted tooth, [C] Bonding with the adjacent tooth, [D] Postoperative- Natural tooth pontic

Provisional fixed partial prosthetic splint

In certain situations, occlusal rehabilitation is complex in nature. In such situations, provisional prosthetic splints play a greater role. If malpositioned teeth have been moved to more acceptable positions, they should be provisionally splinted for several months. Gradually they become stable and further surgical procedures can be initiated for the purpose of regeneration. A provisional splint can be used for anchorage of orthodontic movement of anterior teeth. It allows the periodontist to evaluate the restorative treatment planning. It allows access to the interproximal area during future treatment as it can be easily removed and refitted. It facilitates periodontal treatment by allowing total visibility and access to surgical sites when the splint is removed. The splinting effect enhances healing and periodontal ligament reattachment by stabilizing mobile abutments. The material of choice to fabricate a provisional splint is the heat-processed acrylic resin splint (Itoh *et al.*, 1998; Federick, 1975), *e.g.*, Hawley's retainer.

The definitive fixed partial prosthetic splint:

There are a variety of basic designs of the definitive fixed partial prosthetic bridge that serve the additional purpose of splinting the abutment and other supporting teeth. Conventional crown and bridge prostheses fulfill this requirement very well if adequate abutment teeth are included. Splinting abutment teeth results in a significant decrease in the mesiodistal and buccolingual movements of the distal abutment under vertically applied loads. If lost teeth were replaced by fixed bridges, adjacent teeth should be splinted to serve as an abutment only when the retainer margins could not be placed subgingivally and embrasure made wide enough to maintain proper oral hygiene (Quirynen *et al.*, 1999; Silness and Ohm, 1974).

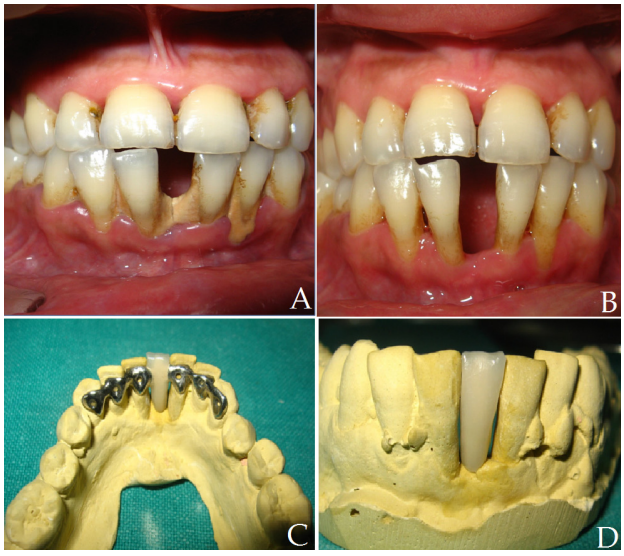

Figure 6: [A] Preoperative photograph of a periodontally compromised lower anteriors, [B] Post non-surgical periodontal therapy, [C] Resin bonded cast metal splint with ceramic pontic (Lingual view), [D] Labial view of ceramic pontic

Optionally, resin-bonded splints can be designed if the anatomy and situation of the teeth are not conducive to slender cement retained fixed prostheses. In such situations a ceramic pontic with metal splint is best suited, stabilizing the adjacent periodontally compromised teeth (*Figure 6*).

Effects of splinting on oral and periodontal health (*Table 1*)

Splinting and oral hygiene:

Splinting makes oral hygiene procedures difficult. Therefore, to ensure the longevity of the connected teeth, special attention must be given to instructing the patient about enhanced measures for oral hygiene after placement of the splint prosthesis. Effective personal plaque control, professional caries risk assessment, and periodontal maintenance are crucial to the longevity of the splint and health of the splinted teeth.

Splinting and periodontal repair:

Many authors believed that mobile teeth may inhibit "periodontal repair." Fixed splinting was advocated believing that it would reduce the mobility of individual teeth during healing, but studies have shown otherwise in the following manner.

1. Splinting of the teeth will not prevent or retard apical downgrowth of plaque (in fact, it will increase) and associated attachment loss.
2. Splinting of mobile teeth before scaling and root planing (SRP), and elimination of potential SRP-induced trauma to the mobile teeth did not have any adjunctive effect on healing (Alkan *et al*., 2001).
3. Tooth mobility increases initially after surgery and subsequently decreases by 24 weeks to about pre-surgical values. Splinting did not reduce the mobility of individual teeth and also did not have any influence on bone and attachment level after osseous surgery (Kegel *et al*., 1979).
4. Splinting of mobile teeth did not have any effect on mobility reduction after initial therapy (Kegel *et al*. 1979).
5. Attachment levels and bone levels were similar in splinted and non-splinted teeth following osseous surgery (Gallers, 1979).

Effect of splint material and thickness on tooth mobility (Table 2):

Although current guidelines for the treatment of mobile teeth and traumatic injuries recommend the use of 'flexible' splints, the specific definition of what is considered flexible versus rigid has not been clearly defined, leaving the clinician with a wide range of options for this critical factor.

Kwan *et al*. (2012) quantified and compared the effect of eight different splints on tooth mobility after extraction and replantation using a human cadaveric model. The experimental splints included 30-pound test monofilament nylon composite and six wire-composite splints made of 0.012" (0.3 mm), 0.016" (0.4 mm), or 0.020" (0.5 mm) diameter stainless steel (SS) or nickel titanium (NT) wires. Following strict selection criteria (complete root maturation, lack of periodontal disease, normal bone levels, and crown integrity), a maxillary central incisor was atraumatically extracted and splinted with eight different splints. These eight splints were applied five times each, and tooth mobility was measured between the pre-split and the post-split measurements quantified using Periotest.

Significant less tooth mobility with direct composite splint compared to all other splints and no differences between nylon-composite and wire composite splints were observed. The authors also suggested that nylon and SS or NT wires up to 0.016" (0.4 mm) diameter are significantly more flexible than direct composite splints and thus may be better suited for the splinting and management of traumatized teeth (Kwan *et al*., 2012).

There are various methods to enhance the bond strength of the wire-composite resin interface of dental splints. One study consisted of 360 bovine mandibular incisors embedded in acrylic resin that were utilized as bonding surfaces for evaluating the bond strength of the wire-composite interface using light-activated (Gluma) and chemically activated (Rely-a-bond) composite resins with both flexible (0.016" round, 0.017" x 0.025" rectangular) and rigid (0.036" round) SS wires. The results of the study indicated that sandblasting the portions of the stainless steel wires embedded in composite resin enhanced the strength of wire-composite bond for both light-activated (Gluma®, Heraeus Kulzer, Hanua, Germany) and chemically activated (Rely-a-Bond®, Reliance Orthodontic Products, Inc., Ithaca, IL) composite materials. The use of a metal primer on stainless steel wires either separately or in combination with sandblasting had lower wire-composite interface bond strength than sandblasting alone, while no surface treatment on the wire had the least bond strength for both the light- and chemically activated composite resins (Jacob and Nandlal, 2003).

Effect of splinting on traumatized teeth

Dental trauma is a common injury, especially in children. Avulsion is a serious injury that can cause damage to some or all of the dental and surrounding tissues. Laser Doppler flowmetry analyses reveal that intrusive luxations are associated with a significant decrease in pulpal blood flow values, while subluxations, lateral luxation, extrusive luxation, and avulsions have not shown such changes. Healing complications of traumatized teeth such as pulp necrosis, root resorption, inflammatory and replacement resorption, and defects in marginal periodontal bone healing may occur (Burcak *et al*., 2006).

The occurrence of these healing complications is related to various treatment factors such as treatment delay, method of repositioning, i.e., expecting re-eruption, orthodontic reposition and surgical reposition, type of splint (rigid, semi-rigid or flexible), the number of splinting days, and the use of antibiotics. Type of splint does not have a significant effect on the type of healing in cases of surgical repositioning of avulsed teeth followed by splinting. Dental splinting is frequently needed following traumatic injuries to stabilize subluxated, luxated, avulsed and root-fractured teeth. The prognosis is determined by the type of injury rather than factors associated with splinting. Duration of splinting is not recommended to be more than 10 days (Kinirons *et al*., 1999; Andreasen *et al*., 2004)

Effects of splinting on periodontium

In a study on rhesus monkeys to determine the effect of splinting on hyperocclusion, it was observed that forces applied to one tooth in a splint are distributed over the entire unit, that is, all the teeth included in that splint, thus reducing the occlusal load on a periodontally compromised tooth and facilitating the distribution of occlusal forces over a larger periodontal surface. Thus, it was concluded that splinting of tooth helps in redistributing the occlusal forces over a larger area. It was also observed that the areas of root bifurcation and trifurcation are more susceptible to excess occlusal forces (Glickman *et al*., 1961).

In another study of 2 weeks in vervet monkeys to determine the effect of rigid splinting on anterior teeth following extrusion of teeth by 3 mm and their replacement back into the socket, the investigators did not observe any significant difference between the splinted and non-splinted teeth in terms of periodontal ligament width or stress or strain values. Results of the study showed that rigid splinting of luxated teeth did not improve the mechanical properties of the periodontal ligament during healing (Mandel and Viidik, 1989).

In a study to determine the effect of initial preparation and occlusal adjustment on tooth mobility, it was observed that for teeth with initial mobility of greater than 0.2 mm there was a decrease in tooth mobility up to 20% (Rateitschak, 1963).

The authors strongly feel that splinting mobile teeth acts as an adjunct to periodontal treatment and maintenance and hence is recommended. However, selecting the right splint for the right procedure is done based on the discretion of the advantages and disadvantages of each. A splint should be designed in such a way that it attracts the least plaque and calculus, is able to be retained for the specified time, is able to carry out its designated function, and does not interfere with healing and esthetics.

Conclusion

Tooth mobility is a common sequel to periodontitis and trauma from occlusion. Mobility, bone loss and attachment loss associated with trauma from occlusion can be reduced by eliminating trauma. Periodontally compromised teeth with poor prognosis can also be retained for a longer time by using splints, until a more definitive treatment is planned for the patient. Provided all the factors are considered and proper maintenance therapy is recommended, splints are becoming an integral part of periodontal therapy and maintenance. However, it should be noted that splinting itself will not eliminate the cause of tooth mobility. They are only an aid in stabilizing the mobile tooth, and mobility may revert once the splints have been removed. Hence, splinting is an essential adjunct in addition to cause-related therapy in the treatment of mobile teeth.

Based on the available data it could be observed that splinting can be considered as an essential part of periodontal treatment to increase the longevity of periodontally compromised teeth with advanced mobility. However, further research is still required to come to a definitive conclusion about the exact role of splints, and patient selection criteria for splinting in periodontal treatment.

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