Dental Traumatology

Dental Traumatology 2012; **28**: 277–281; doi: 10.1111/j.1600-9657.2011.01086.x

The effect of splint material and thickness on tooth mobility after extraction and replantation using a human cadaveric model

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Accepted 23 October, 2011

Abstract – Although current guidelines for the treatment of traumatic injuries recommend the use of 'flexible' splints, the precise definition of what is considered flexible versus rigid has not been rigorously defined, leaving the clinician with a wide range of options for this critical factor. The purpose of this study was to quantify and compare the effect of eight different splints on tooth mobility after extraction and replantation using a human cadaveric model. Following strict selection criteria including 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. The experimental splints included a 30-pound test monofilament nylon-composite splint and six wire-composite splints made of wires 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). A direct composite splint represented the most rigid type of splint. These eight splints were applied five times each, and tooth mobility was measured before and after each splint was applied. The average splint effect, defined as the difference between the presplint and the postsplint measurements quantified using the Periotest, was calculated for each splint and compared. No significant differences were found between the nylon-composite and the wire-composite splints. There was significantly less tooth mobility with the direct composite splint compared to all other splints. In conclusion, the results of this study suggest that nylon and SS or NT wires up to 0.016′ diameter are significantly more flexible than direct composite splints and thus may be better suited for the splinting and management of traumatized teeth.

The management of dental trauma remains a significant clinical challenge affecting health-care providers and patients alike. Falls, accidents, sporting injuries, and physical assaults are the most frequent causes of dental trauma (1–4) with maxillary centrals being the most commonly injured teeth (3, 5, 6). Although most studies agree that males are injured at a greater rate than females (2, 3, 5–7), they disagree on the most common age range, with various authors citing the highest incidence at 7–9 years old (1), 8–12 years old (5, 8), 10–13 years old (6), and 16–20 years old (2). Overall, the estimated prevalence of injuries among children is 30% (3, 4, 9, 10). Patients can present with a wide variety of injuries, ranging from damage to the tooth itself, such as crown or root fractures, to injuries to the supporting periodontal structure, including luxations and avulsions.

One of the critical phases of the treatment of traumatized teeth is the splinting or stabilization of the affected teeth. Nasjleti et al. (11) in 1982 demonstrated that replanted teeth that were splinted for 7 days healed with new periodontal ligament (PDL), while teeth splinted for 30 days developed more inflammatory and replacement resorption. Mandel and Viidik (12) demonstrated that the PDL achieved 70% of its original strength 14 days after extraction and replantation. Current literature has reinforced the importance of using a flexible splint to stabilize the teeth, allowing physiological movement of the traumatized teeth (7, 13–15). Based on all the available evidence, current treatment guidelines for traumatized permanent teeth recommend the use of a flexible splint, regardless of the type of trauma (16–18). Splinting time varies based on the presence of alveolar fracture and type and severity of the injury. However, the precise definition of what is considered flexible versus rigid has not been rigorously defined, thus leaving the clinician with a wide range of options for this critical factor.

Numerous types of splints have been described in the literature, including wire-composite, nylon fishing line-composite, Ribbond, wire-cyanoacrylate, direct composite, titanium trauma, titanium ring, button-bracket, Schuchardt, and suture splints (9, 16, 18–25). Different methodologies have been used to evaluate splint rigidity, including acrylic resin artificial models (22), monkeys

(26, 27), sheep mandibles (28), uninjured human teeth (10, 19), and injured human teeth (29). Although *in vivo* randomized controlled trials should be considered the highest level of evidence, it would require a large sample size to overcome confounding clinical variables such as the type and severity of the injury, patient's dental age, and stage of root development, which are unavoidable and will directly influence the result of the study. Recently, Berthold et al. (22) used an acrylic resin model to compare the rigidity of different types of splints and stated that flexible or semi-rigid splints such as the titanium trauma splint and 0.4-mm wire-composite splints are appropriate for splinting teeth with luxation injuries and root fractures. This model lacks clinical relevancy as no periodontal ligament was present and tooth mobility was completely artificially created. Therefore, the purpose of this study was to quantify and compare the effect of eight different splints on tooth mobility after extraction and replantation using a human cadaveric model.

Materials and methods

Cadaver selection and tooth extraction

A single cadaver (elderly Caucasian male) presenting with all maxillary incisors and canines was selected based on a criterion that included complete root maturation, lack of severe periodontal disease, and crown integrity. The cadaver contained no identifiable data, and our study was conducted prior to the gross anatomy class, where the cadavers were fully dissected by medical and dental students. These cadavers were the remains of individuals who had previously consented before their deaths that their bodies could be used for medical and dental research and teaching. A cone beam computed tomography (Mercuray, Hitachi Medical Corporation, Osaka, Japan) scan was taken to confirm normal anatomy of the roots and periodontium. The images demonstrated no pathology and a normal bone loss. The maxillary left central incisor was extracted atraumatically using a periotome, elevator, and forceps, without further injury to the adjacent teeth, alveolar bone, and soft tissue. The tooth was extracted, moistened, and replanted between splint measurements to confirm its loosening and prevent tissue desiccation.

Splints

Experimental splints were selected based on the metallurgic and the diameter of the wire and were applied using the wire-composite technique (10). Accordingly, six wire-composite splint types were tested using stainless steel (SS) or nickel titanium (NT) wire with 0.012′ (0.3 mm), 0.016′ (0.4 mm), or 0.020′ (0.5 mm) diameter (3M Unitek, Monrovia, CA, USA). A 20-pound test monofilament nylon fishing line (Pacifica, Taiwan) and a rigid direct composite splint were also tested, representing the flexible and rigid ends of the flexibility spectrum, respectively. All splints extended from canine to canine and were applied using the same composite (TPH3; Dentsply, York, PA, USA) and bonding resin (AllBond 2; Bisco, Schaumburg, IL, USA). The direct composite splints were created by bonding a rope of composite directly onto and across teeth. The splints were removed between each measurement using a high-speed handpiece with a diamond or carbide bur.

Mobility measurements

The mobility of the splinted tooth was measured using the Periotest M (Medizitechnik Gulden, Germany) (30), a commercial device used to measure the mobility of teeth and implants. This instrument has been widely used and described in the trauma literature (9, 19, 22, 31). Measurements, which range from −8 to +50 with lower numbers representing less mobility, are highly reproducible (22). Unlike the standard 0–3 clinical mobility scale, the greater resolution of the Periotest device allows it to detect small changes in tooth mobility with high reliability, and its values have been correlated to the 0–3 scale.

Three Periotest readings were taken on the avulsed tooth both before and after each splint were applied. The tooth was extracted and replanted between each splint. The wire-composite and nylon-composite splints were applied and removed in random order. This process was repeated five times, with a different randomization order within each repetition of the experiment. Because of the concern that bonding resin or composite might flow interproximally between the adjacent untraumatized teeth, the five applications and removals of the direct composite splint were performed last.

Statistical analysis

To evaluate whether repeated splint application, splint removal, and periotest measurements affected the cadaver model, a linear regression analysis was used to test for a linear trend of the presplint mobility measurements as a function of time. A Wald test was used to determine the statistical significance of the linear trend.

The splint effect, defined as the change in periotest value before and after splinting, of each splint was calculated and compared using analysis of variance (ANOVA) methods. The primary analysis used a 2-way main effects ANOVA model to test for differences between the six wire-composite splints by the type of metal used (SS vs NT) or by splint thickness (0.012′, 0.016′, or 0.020′). As a secondary analysis, Kruskal–Wallis tests were used to make pairwise comparisons between the control splints (nylon-composite and direct composite) and each of the other splint types.

Results

Validation of the research model

The 40 presplint mobility measurements are plotted as a function of time in Fig. 1; the linear trend was statistically significant ($P = 0.01$). The regression coefficient of 0.31 (95% confidence interval: 0.07, 0.56) suggests that on average the presplint mobility increases 0.31 periotest units per splint repetition.

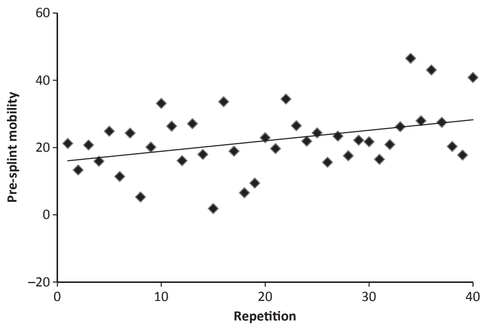

Fig. 1. Presplint mobility increased as experiment progressed. Regression coefficient = 0.31 (P = 0.01).

Similarly, a slightly increasing trend was observed within each splint for the postsplint mobility. However, the splint effect did not show any time trend (data not shown). Thus, although the cadaveric tissues had some degree of loosening as the experiment progressed, the use of the splint effect as the primary outcome variable eliminated this systematic bias.

Effect of the splints on tooth mobility

The average splint effect for each of the eight splints is displayed in Fig. 2. Among the wire-composite splints, tooth mobility was similar for all NT splits, regardless of thickness. Among SS splints, there was a trend of decreased mobility (larger splint effect) with increased splint thickness. In the analysis of variance model, however, neither splint material (SS or NT) nor splint thickness (0.012′, 0.016′, or 0.020′) of the wire-composite splints was associated with a significant effect on tooth mobility. The P-values for splint material and thickness were 0.61 and 0.16, respectively. An interaction term between material and thickness was included in the ANOVA model to test whether there is an association between mobility and splint thickness, which differs by splint material type. The interaction term was not significant (P = 0.34).

The splint effect of the direct composite splint [mean (standard error) = 31.7 (5.7)] was significantly greater than that of the nylon-composite splint [6.2 (2.5), P < 0.01], all three NT wire-composite splints [10.9 (3.8), P = 0.02 for 0.012′; 13.4 (3.6), P = 0.02 for 0.016′; 13.3 (4.0), P = 0.03 for 0.020′], and the 0.012′ [4.8 (4.5), P < 0.01] and 0.016′ [9.1 (3.0), P < 0.01] SS wire-composite splints. Although the splint effect of the 0.020′ SS wire-composite splint [18.6 (5.5), P = 0.18] was less than the direct composite splint, the difference was not statistically significant at this sample size. No significant differences were seen between the nylon-composite splint and any of the wire-composite splints, or between the wire-composite splints (P > 0.05).

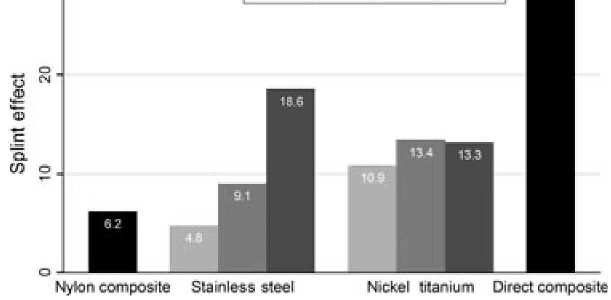

Fig. 2. Effect of splint on tooth mobility.

Discussion

To our knowledge, this study is the first to use a cadaveric model to evaluate the effect of splints on tooth mobility. Although higher evidence-based research is always preferable, a prospective randomized study would require a large sample size to overcome confounding variables such as the type and severity of the injury, the presence of concomitant alveolar fracture, the dental age of the patient, and the stage of root maturation. On the other hand, the use of *in vitro* studies, such as the one developed by Berthold et al. (22) using acrylic resin models, while well controlled, lacks clinical relevancy as they do not resemble the human periodontium. By using a human cadaver, we have attempted to replicate the *in vivo* conditions while controlling the clinical variables directly related to the effect of splints on teeth mobility. The periodontal condition of the cadaver was consistent with the patient's age at the time of death, and no vertical bone loss or severe periodontal disease was observed. The effect of splint type on tooth mobility was compared under the exact same clinical situation, and results obtained are therefore reliable. Nevertheless, because this is not a clinical study, physiological outcomes of treatment cannot be predicted from this study alone.

Inherent limitations of such a model are mainly related to the lack of a vital periodontium. Most notable was the gradual increase in the presplint mobility as the experiment progressed, as seen by the positive linear trend in mobility. It is likely that the periodontium was slightly compacted with each repetition, resulting in a larger socket and thereby looser tooth. Although this increase was small, just 0.31 periotest units per experiment, it was not insignificant. However, this repeated splinting and removal also likely affects other models that use similar methodology.

The study design allowed for valid comparison of tooth mobility by splint type. First, we collected measures of both presplint and postsplint mobility for each splint application and calculated the change in mobility (splint effect). By using the splint effect as the study outcome, the systematic changes in the mobility measurements are accounted for. The splint effect did not show a significant time trend. Also, randomization of splint types within each repetition reduces the chance of systematic bias in the study results.

Another limitation of this study was the use of a single cadaver. Although this study was performed to eliminate confounding variables, it is possible that these results may not be relevant to other cadavers. However, this type of extrapolation from a single model system appears to be widely accepted in the literature (15, 22). The use of single cadaver also necessitated the removal of the splints multiple times. However, the slight increase in mobility with each repetition was controlled for as described earlier.

The direct composite splint was significantly more rigid than all other splints except the 0.020′ SS wire-composite splint, which did not reach significance with the given sample size. Although not significant, the expected trend of increasing splint effect was observed with thicker wires, most notably with SS. Therefore, it may be reasonable to assume that wires with diameter $>0.016'$ (0.4 mm) may result in significantly more rigidity of the splint, particularly if using SS wires. Although the critical thickness threshold was not calculated in this study, our results suggest that 0.016′ SS splint may be considered as a clinical threshold between what we consider flexible and non-flexible splints.

Overall, these results suggest that a flexible splint would be made using nylon fishing line or thin wire and composite. Direct composites splints and wire-composite splints made with wire $>0.016'$ (0.4 mm) in diameter may not allow physiological mobility. Although the clinician may choose whether to use nylon fishing line or wire based on personal preferences, the nylon-composite splint may offer a few advantages. Clear fishing line with composite that matches the tooth shade could provide a more esthetic result than a metal wire bonded across the front teeth. It is also composed of less expensive materials and may be more easily applied and removed than a wire-composite splint (26).

Conclusion

Based on evidence-based literature, current protocols and guidelines have stressed the importance of using flexible splints for the stabilization of traumatized teeth. The results of this study provide clinicians with critical information regarding the effect of different splints on tooth mobility, thus allowing them to choose the most appropriate splint that will allow physiological movement during stabilization and regeneration of the traumatized periodontium.

Acknowledgements

The authors would like to thank Dr Susan W. Herring for her assistance in this project.

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