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Rigidity of commonly used dental trauma splints

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Abstract – *Background/Aims:* The stability of immobilization devices varies from flexible to rigid, depending on the trauma. We evaluated the rigidity of various commonly used splints *in vitro*. *Material and Methods:* An acrylic resin model was used. The central incisors simulated injured teeth, with increased vertical and horizontal mobility. The lateral incisors and canines stimulated uninjured teeth. Tooth mobility was measured with the Periotest® device. Vertical and horizontal measurements were made before and after splinting, and the difference between values was defined as the splint effect. We evaluated 4 composite splints, 3 wire-composite splints, a titanium trauma splint, a titanium ring splint, a bracket splint, and 2 Schuchardt splints. *Results:* For all injured teeth and all splints, there was a significant splint effect for the vertical and horizontal dimensions ($P < 0.05$). For injured teeth, the composite splints produced the largest changes in vertical tooth mobility; wire-composite splints 1 and 2, using orthodontic wires, produced the smallest vertical splint effects. For uninjured teeth, the Schuchardt 1 splint and the bracket splint produced the largest splint effects; wire-composite splints 1 and 2 produced only a slight change in tooth mobility. Composite splints 2 and 3 produced the largest horizontal splint effects for injured teeth, and the 4 composite splints produced the largest horizontal splint effects for uninjured teeth. The most horizontally flexible splints were the titanium trauma splint and wire-composite splints 1 and 2. *Conclusions:* According to the current guidelines and within the limits of an *in vitro* study, it can be stated that flexible or semirigid splints such as the titanium trauma splint and wire-composite splints 1 and 2 are appropriate for splinting teeth with dislocation injuries and root fractures, whereas rigid splints such as wire-composite splint 3 and the titanium ring splint can be used to treat alveolar process fractures.

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Over the last four decades knowledge about healing of traumatically dislocated teeth has grown, and treatment principles have changed. It was shown that extended splinting periods with rigid immobilization can increase the risk of healing complications (1–5). Studies on monkeys demonstrated uneventful periodontal healing when artificially avulsed teeth were physiologically loaded without splinting (2, 4), but it also was reported that a small portion of these experimentally replanted teeth were lost during the healing period (4). These findings suggest that treatment of dislocated teeth should involve repositioning followed by splinting, which enables application of a physiological load to injured teeth. Splints should facilitate repositioning of displaced teeth to their original location and also ensure adequate fixation, preventing accidental ingestion or inhalation. In addition, they protect teeth against traumatic forces during the vulnerable healing period (6).

There are several recommended splinting methods for dislocated and root-fractured teeth (6–22). For a long time, tooth fixation was based on the principles of immobilization for fractures of the jaw bone or alveolar process (7–9). After Buonocore developed acid etching for enamel (23), splinting techniques using resin composites alone (12, 14, 24) or in combination with wires (6, 15, 20, 25–27), as well as commercially available splinting systems (16–19, 27), were introduced. Depending on the type of trauma, the stability of fixation devices can vary from flexible to rigid.

Only a few studies have focused on splint rigidity (14, 15, 17, 19, 24, 25, 28, 29). Most of these studies used artificial models (17, 24, 28, 29); other investigations were performed *in vitro* using animal models (14, 25) or *in vivo* using uninjured (19) or injured human teeth (15). The aim of this study was to evaluate the rigidity of various commonly used dental trauma splints.

Materials and methods

Model

For this *in vitro* study, an artificial model (KaVo EWL, Leutkirch, Germany) with acrylic resin teeth was used. The central incisors (teeth 11 and 21) simulated traumatized teeth with increased vertical and horizontal mobility, whereas the lateral incisors (teeth 12 and 22) and the canines (teeth 13 and 23) served as uninjured teeth with normal mobility. To enable small vertical and horizontal movement of the injured central incisors, the fastening mechanism in the apical part of the root was removed. The empty part of the socket was filled with a soft silicon impression material (Xantopren® Comfort light; Kulzer, Dormagen, Germany), and the shortened teeth were replanted. Uninjured lateral incisors and canines were inserted and locked with the prefabricated fastening mechanism. To ensure comparable results, the same model was used for all experiments.

Splints

Twelve different splints were tested, including four composite splints (CS 1–4; Fig. 1) (12, 14, 24), three wire-composite splints (WCS 1–3; Figs 2–4) (15, 19, 20, 25), two commercially available trauma splints (titanium ring splint, TRS; titanium trauma splint, TTS; Figs 5 and 6) (16, 18, 19), a bracket-splint (BS; Fig. 7) (6, 19, 20), and two versions of the Schuchardt splint (SS 1 and 2; Fig. 8) (9). The materials used for each splint and the fixation methods are described in Table 1. The Schuchardt splints were extended to the second premolars. All other splints were fixed to the labial aspect of the maxillary incisors and canines. Each splint was applied 10 times.

Fig. 1. Composite splint (CS 1–4). Resin composite was bonded interdentally to connect adjacent teeth.

Fig. 2. Wire-composite splint 1 (WCS 1). The splint was created by fixing a multi-stranded flexible orthodontic wire (0.45 mm) to the middle part of the labial surface using flowable composite.

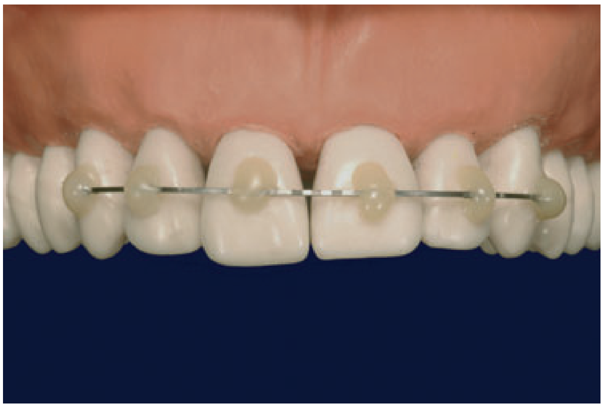

Fig. 3. Wire-composite splint 2 (WCS 2). The splint was made using a rectangular orthodontic wire (0.41 mm × 0.41 mm) fixed with light-cured flowable composite.

Fig. 4. Wire-composite splint 3 (WCS 3). The splint was created using three-stranded strengtheners (0.8 mm × 1.8 mm) fixed with flowable composite.

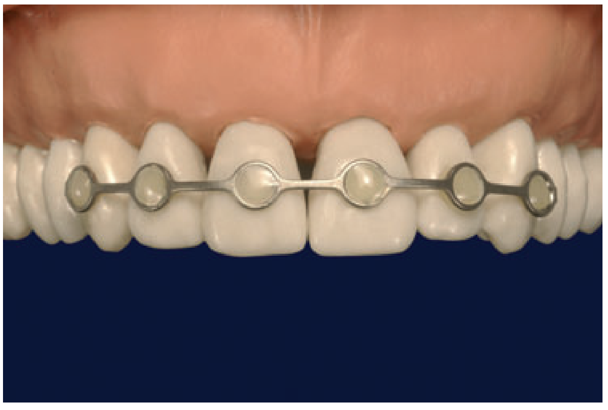

Fig. 5. Titanium ring splint. A commercially available 0.6-mm-thick trauma splint was bonded to the labial surface.

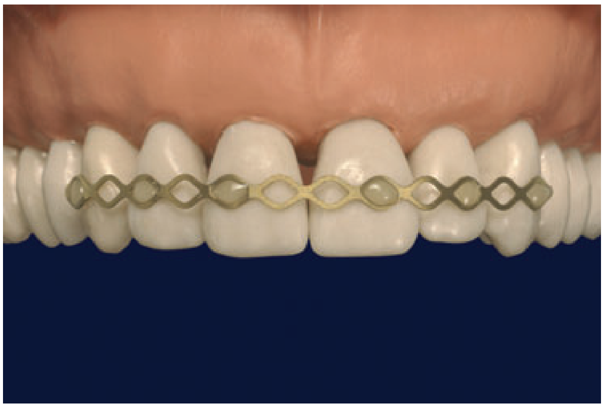

Fig. 6. Titanium trauma splint. A commercially available 0.2-mm-thick trauma splint was bonded to the labial surface using flowable composite.

Fig. 7. Bracket splint. Bonded button brackets were connected by twisting 0.4-mm soft wire around the buttons. Twisted wire ends were covered with flowable composite (tooth 13).

Fig. 8. Schuchardt splints (SS 1 and SS 2). A 1.5-mm half-round wire was bent to fit the vestibular arch bar contour and affixed to the teeth using 0.4-mm soft ligature wire. For SS 1 (left), only wire ligatures were applied. For SS 2 (right), the twisted ends were covered with flowable composite.

Measurement of tooth mobility and splint effect

The Periotest® device (Gulden, Bensheim, Germany) was used to measure vertical and horizontal mobility of traumatized and uninjured teeth. Vertical and horizontal Periotest values (PTVs) were measured three times and averaged for each tooth before (PTVpre) and after (PTVpost) splint insertion. The splint effect was defined as the change in tooth mobility, calculated as the difference between PTVpre and PTVpost (ΔPTV = PTVpre–PTVpost).

Statistical analysis

Data were transferred to SPSS 14.0 (SPSS Inc., Chicago, IL, USA) for statistical analysis. Horizontal and vertical PTVpre, PTVpost, and ΔPTV were not normally distributed (Kolmokorov–Smirnow test, $P < 0.05$). Therefore, nonparametric tests were applied. The Wilcoxon test ($P < 0.05$) was used to compare the three PTV measurements and PTVpre and PTVpost (paired samples). The Mann–Whitney U-test ($P \leq 0.001$) was used to compare the splint effect of the various splint types (unpaired samples).

Results

Mobility measurements

We recorded 8640 PTVs, 720 per splint type. No statistically significant differences were found between the three repeated PTV measurements ($P < 0.05$). Descriptive statistics (mean and standard deviation) for the vertical and horizontal PTVpre showed a statistical spread (Tables 2 and 3). Thus, PTVpre was used as a covariate in analysis of splint effects.

Vertical PTVpre and PTVpost

Comparison of vertical PTVs before and after splinting showed a change in vertical tooth mobility. There were statistically significant differences between PTVpre and PTVpost for injured central incisors in all cases, but for WCS 1 and WCS 2 on tooth 11 ($P < 0.05$). Decreased mobility was also found for uninjured lateral incisors and canines, but changes in vertical mobility for canines were often not statistically significant.

Horizontal PTVpre and PTVpost

Compared to the changes in vertical mobility, there were more considerable reductions in horizontal mobility for both injured and uninjured teeth. Except for the WCS 1 (tooth 22) and the TTS (tooth 23), all inserted splints produced a significant change in lateral tooth mobility ($P < 0.05$).

Vertical splint effects

The mean vertical splint effect and standard deviation for all splint types for the different teeth are shown in Table 4. Positive values indicate decreased tooth mobility, and negative values indicate increased tooth mobility. Also comparison of splint effects for the various splints are shown for injured and uninjured teeth.

Table 1. Materials and fixation methods for tested splints

No.	Name	Materials	Splint type	Fixation method	Reference
1	WCS 1	Teric®flow and 0.45-mm Dentaflex® (Dentaurum, Pfortzheim, Germany)	Wire-composite splint	1. Contour wire to dental arch 2. Roughen vestibular middle crown	(20, 25)
2	WCS 2	Teric®flow and 0.4 × 0.4-mm wire (Dentaurum)		3. Bond	(15, 19)
3	WCS 3	Teric®flow and 0.8 × 1.8-mm strengtheners (Dentaurum)		4. Fix wire using flowable composite	(20, 25)
4	TRS	Teric®flow and titanium ring splint (Mondeal Medical Systems, Tuttlingen, Germany)	Commercially available trauma splint	1. Contour titanium splint to dental arch 2. Roughen vestibular middle crown 3. Bond 4. Fix splint using flowable composite on prefabricated openings	(16)
5	CS 1	Protemp®II Garant (3M Espe, Seefeld, Germany)	Composite splint	1. Roughen approximal crown surface to simulate acid etching of enamel	(12, 14, 24)
6	CS 2	Teric®flow (Ivoclar-Vivadent, Schaan, Liechtenstein)			
7	CS 3	Luxatemp® (DMG, Hamburg, Germany)		2. Bond	
8	CS 4	Rely X Unicem® (3M Espe, Seefeld, Germany)		3. Apply composite between teeth in the contact region	
9	SS 1	1.5-mm half-round wire and 0.4-mm ligature wire (Dentaurum)		1. Contour half-round wire to dental arch 2. Fix wire using wire ligatures around each tooth	(9)
10	SS 2	1.5-mm half round wire, 0.4-mm ligature wire, and Luxatemp®		Step 1 and 2 like SS 1 3. Cover ligatures and wire with resin	
11	TTS	Teric®flow and titanium trauma splint (Medartis, Basel, Switzerland)	Commercially available trauma splint	1. Contour titanium splint to dental arch 2. Roughen vestibular middle crown 3. Bond 4. Fix splint using flowable composite on prefabricated openings	(18, 19)
12	BS	Teric®flow, Buttonbracket, and 0.4-mm ligature wire (Dentaurum)	Bracket splint	1. Roughen vestibular middle crown 2. Bond 3. Fix brackets using flowable composite 4. Apply ligature wire around brackets	(6, 19, 20)

Table 2. Mean vertical PTVpre for each individual tooth and for central incisors (teeth 11 and 21), lateral incisors (teeth 12 and 22), and canines (teeth 13 and 23)

Tooth	PTVpre v: Mean (SD)	Teeth	PTVpre v: Mean (SD)
11	8.840 (2.623)	11 + 21	11.976 (2.277)
21	15.120 (2.975)		
12	4.380 (1.340)	12 + 22	1.975 (1.219)
22	−0.430 (1.986)		
13	−1.340 (1.442)	13 + 23	−2.506 (0.809)
23	−3.670 (1.503)		

Table 3. Mean horizontal PTVpre for each individual tooth, central incisors (11 and 21), lateral incisors (12 and 22), and canines (13 and 23)

Tooth	PTVpre h: Mean (SD)	Teeth	PTVpre h: Mean (SD)
11	39.48 (5.139)	11 + 21	39.350 (5.400)
21	39.22 (7.390)		
12	13.41 (1.847)	12 + 22	12.331 (1.608)
22	11.25 (3.036)		
13	9.51 (1.869)	13 + 23	7.244 (1.299)
23	4.98 (2.769)		

For injured teeth, the largest vertical splint effect was produced by CS 3, followed by CS 1, CS 2, and CS 4; the smallest splint effects were produced by WCS 1 and WCS 2 (Fig. 9). Pairwise comparisons of the splint effects of the various splints revealed statistically significant differences in most cases. Exceptions were WCS 1 vs WCS 2, TRS vs WCS 3, SS 1 vs WCS 2, WCS 3 and TRS, CS 1 vs CS 2 and CS 3, CS 2 vs CS 4 and SS 2, CS 4 vs SS2, and BS vs TRS and SS 1 ($P > 0.001$; Table 4).

As with injured teeth, WCS 1 and WCS 2 produced only slight splint effects for uninjured teeth (Fig. 10). In contrast, SS 1 and BS produced the largest splint effects for uninjured teeth. Pairwise comparisons of most splints revealed significant difference in rigidity. No statistically significant differences were found between TTS and WCS 1–3 or TRS, TRS and SS 1 or WCS 3, WCS 1 and WCS 2, or BS and SS2. Also no statistically significant differences were found between all composite splints ($P > 0.001$; Table 4).

Horizontal splint effects

The mean horizontal splint effects and the standard deviations for injured and uninjured teeth are shown in Table 5. Also results of pairwise splint comparisons are shown for injured and uninjured teeth.

For injured teeth, CS 2 and CS3 produced the largest horizontal splint effects, while the lowest rigidity was observed for TTS and WCS 1 (Fig. 11). There were statistically significant differences in rigidity between most pairs of splints (Table 5). However, no differences were found for WCS 3 vs TRS, CS 1 and CS 4, for TRS vs CS 1 and CS 4, for CS 2 vs CS 3, and for CS 4 vs BS ($P > 0.001$).

Table 4. Mean (SD) vertical splint effects for injured and uninjured teeth

Splint	Injured teeth				Uninjured teeth							
	11	21	CI (11 + 21)	*	12	22	LI (12 + 22)	13	23	C (13 + 23)	LI + C	**
WCS 1	0.00 (1.287)	2.97 (3.624)	1.48 (1.850)	A	−1.33 (1.028)	0.33 (0.758)	−0.50 (0.587)	−1.10 (1.006)	0.77 (1.223)	0.17 (0.723)	−0.17 (0.484)	1
WCS 2	−0.40 (2.415)	2.30 (2.907)	0.95 (1.328)	A, B	−0.80 (1.495)	−0.67 (1.348)	−0.73 (1.135)	−1.07 (1.031)	0.13 (0.346)	0.17 (0.547)	−0.28 (0.639)	1
WCS 3	4.60 (3.024)	7.83 (3.435)	6.22 (2.413)	A	3.23 (1.675)	−0.73 (1.617)	1.25 (1.097)	1.00 (1.208)	−0.33 (0.479)	−0.02 (0.650)	0.62 (0.639)	1
TRS	6.07 (3.393)	8.73 (2.959)	7.40 (2.098)	A, C	3.40 (1.567)	−0.50 (1.225)	1.45 (1.061)	3.17 (0.785)	0.07 (0.254)	0.07 (0.365)	0.76 (0.571)	1, 2
CS 1	10.40 (3.081)	18.40 (3.829)	14.40 (2.339)	D	7.40 (1.162)	0.00 (2.841)	3.70 (1.638)	4.63 (0.923)	0.60 (1.276)	0.85 (0.721)	2.27 (0.929)	3
CS 2	8.40 (2.061)	17.07 (3.600)	12.73 (2.258)	D, E	4.23 (4.446)	2.03 (1.351)	3.13 (2.389)	9.03 (2.975)	−0.27 (1.051)	1.70 (1.611)	2.42 (1.341)	3
CS 3	11.90 (4.358)	20.13 (3.17)	16.02 (3.117)	D	5.37 (2.157)	3.33 (1.516)	4.35 (1.340)	0.93 (0.785)	−0.17 (0.834)	0.38 (0.520)	2.37 (0.700)	3
CS 4	8.37 (1.903)	15.70 (2.879)	12.03 (1.776)	E	7.73 (1.818)	1.97 (0.669)	4.85 (0.892)	0.33 (0.758)	0.07 (1.507)	0.20 (0.847)	2.52 (0.614)	3
SS 1	4.67 (1.213)	10.43 (1.995)	7.55 (1.177)	A, F	1.63 (1.189)	3.90 (2.354)	2.77 (1.172)	−0.20 (0.664)	0.10 (0.607)	−0.05 (0.497)	1.36 (0.665)	2
SS 2	8.13 (1.106)	15.67 (1.539)	11.90 (1.125)	E	5.33 (0.884)	4.83 (1.840)	5.08 (1.009)	1.00 (0.910)	1.67 (0.922)	1.31 (0.573)	3.16 (0.572)	4
TTS	1.43 (1.763)	4.70 (1.985)	3.07 (1.350)		0.40 (1.070)	0.30 (0.466)	0.35 (0.604)	0.00 (0.871)	0.23 (0.774)	0.12 (0.639)	0.23 (0.459)	1
BS	7.50 (1.961)	10.80 (4.286)	9.15 (2.613)	C, F	7.23 (1.194)	3.67 (1.3229	5.45 (0.959)	0.70 (1.022)	1.90 (0.845)	1.30 (0.702)	3.37 (0.718)	4

Mean values with same letters (*) and same numbers (**) are not statically significant at $P \leq 0.001$. CI, central incisors; LI, lateral incisors; C, canines.

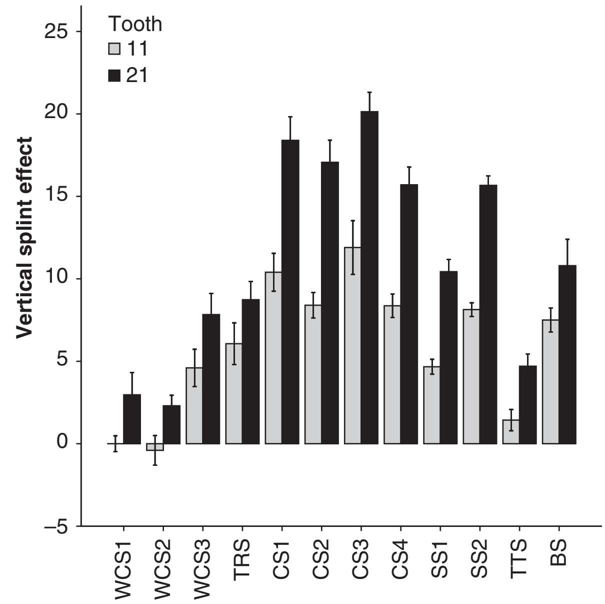

Fig. 9. Vertical splint effects of the various splints for injured teeth 11 and 21.

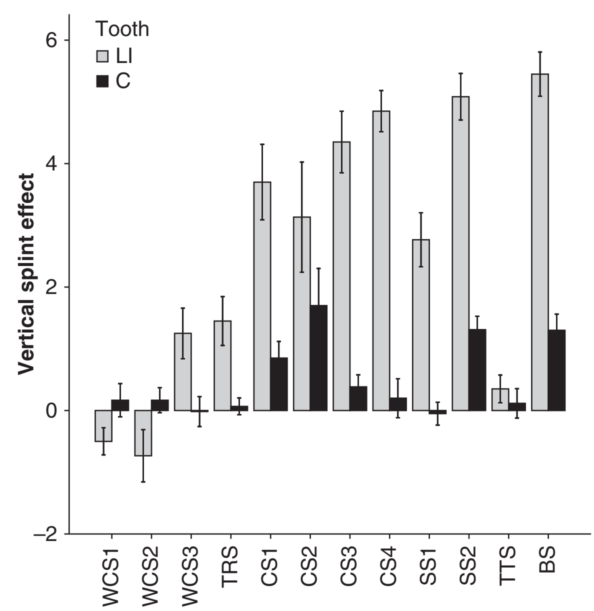

Fig. 10. Vertical splint effects for uninjured lateral incisors (LI) and canines (C).

For uninjured teeth, the most rigid splints were the composite splints, with CS 2 producing the largest splint effect, followed in descending order by CS 1, CS 4, and CS 3. The smallest splint effect was achieved by WCS 1 and WCS 2, with a slightly larger effect with TTS (Fig. 12). Generally, there were statistically significant differences between splint types ($P < 0.001$). However, no significant differences were observed between WCS 1 and WCS 2, between WCS 3 and TTS, between CS 1 and CS 3 or CS 4, between CS 3 and CS 4, and between SS 2 and BS (Table 5).

Table 5. Mean (SD) horizontal splint effects for injured and uninjured teeth

Splint	Injured teeth 11	21	CI (11 + 21)	*	Uninjured teeth 12	22	LI (12 + 22)	13	23	C (13 + 23)	LI + C	**
WCS 1	11.97 (3.068)	17.27 (2.067)	14.62 (2.066)		1.00 (0.830)	0.43 (1.773)	0.72 (0.997)	−1.10 (0.712)	−1.30 (0.794)	−1.20 (0.551)	−0.24 (0.699)	1
WCS 2	17.63 (3.200)	20.97 (2.205)	19.39 (2.058)		0.90 (1.242)	4.30 (1.264)	2.60 (0.824)	−1.07 (1.285)	−2.20 (1.324)	−1.63 (0.753)	0.48 (0.666)	1
WCS 3	27.40 (1.659)	35.27 (1.911)	31.33 (1.341)	A	5.10 (1.029)	4.30 (1.149)	4.70 (0.794)	1.00 (0.788)	−2.37 (0.765)	−0.68 (0.517)	2.01 (0.506)	3
TRS	33.17 (3.514)	33.00 (2.181)	33.08 (2.142)	A	5.81 (2.280)	5.13 (2.255)	5.47 (1.751)	3.17 (0.791)	−1.70 (1.149)	0.73 (0.751)	3.10 (1.058)	
CS 1	39.07 (2.243)	32.50 (9.519)	35.78 (4.972)	A	10.87 (0.681)	7.83 (1.967)	9.35 (0.957)	4.63 (0.718)	2.60 (1.694)	3.62 (0.971)	6.48 (0.798)	2
CS 2	40.7 (1.418)	44.93 (0.980)	42.82 (0.846)	B	9.50 (2.751)	7.60 (2.848)	8.55 (2.027)	9.03 (1.732)	4.30 (1.119)	6.67 (1.045)	7.63 (1.037)	
CS 3	41.87 (1.383)	41.90 (3.155)	41.88 (1.832)	B	10.40 (0.968)	7.27 (1.048)	8.83 (0.620)	4.30 (0.750)	2.73 (0.740)	3.52 (0.549)	6.17 (0.492)	2
CS 4	29.83 (7.047)	31.37 (4.106)	30.60 (4.229)	A, C	11.13 (0.900)	7.00 (1.509)	9.07 (0.848)	3.73 (0.785)	3.30 (0.119)	3.52 (0.565)	6.29 (0.483)	2
SS 1	27.43 (1.040)	17.00 (2.853)	22.22 (1.649)		6.10 (1.689)	5.93 (2.572)	6.02 (1.704)	1.87 (0.208)	2.97 (0.765)	2.42 (0.766)	4.22 (1.163)	
SS 2	27.87 (2.270)	22.90 (1.647)	25.38 (1.096)		5.90 (1.561)	9.13 (3.350)	7.52 (1.882)	1.93 (1.437)	3.00 (2.017)	2.47 (1.245)	5.01 (1.291)	4
TTS	13.07 (2.753)	10.10 (2.155)	11.58 (1.548)		2.00 (0.983)	4.80 (1.297)	3.40 (0.824)	0.73 (1.081)	0.27 (1.230)	0.50 (0.809)	1.95 (0.581)	3
BS	26.63 (0.669)	30.50 (3.319)	28.57 (1.760)	C	7.77 (2.431)	9.10 (0.923)	8.43 (1.244)	1.57 (1.073)	2.87 (1.074)	2.22 (0.727)	5.32 (0.698)	4

Mean values with same letters (*) and same numbers (**) are not statically significant at $P \leq 0.001$. CI, central incisors; LI, lateral incisors; C, canines.

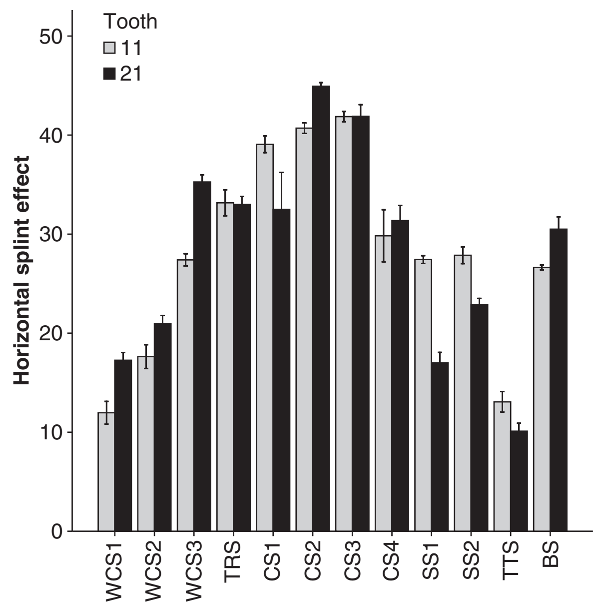

Fig. 11. Horizontal splint effects of the various splints for injured teeth 11 and 21.

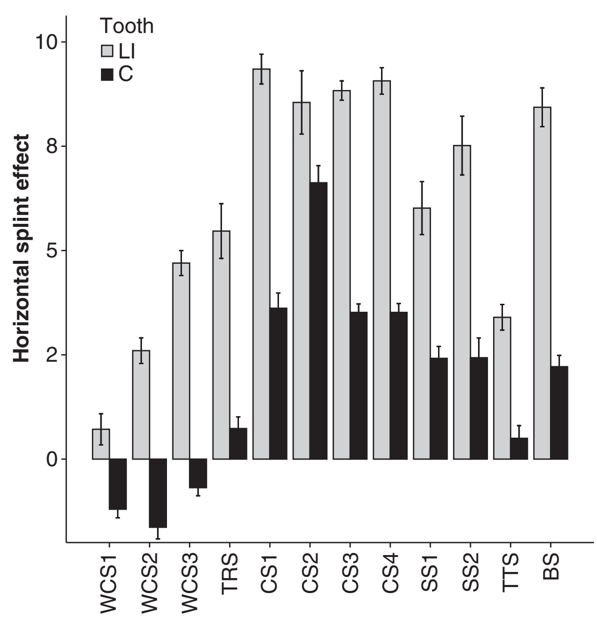

Fig. 12. Horizontal splint effects for uninjured lateral incisors (LI) and canines (C).

Discussion

Splints

The present study evaluated the rigidity of 12 commonly used dental trauma splints.

Modern tooth splinting requires splints that can be created quickly outside the laboratory using conventional dental materials and that are easy to apply, inexpensive, and easy to remove without damaging dental hard tissue (6, 20). Splints should not traumatize teeth or surrounding tissues and should not interfere with occlusion, dental hygiene, or endodontic treatment. Minimally, they should help to restore the original anatomical tooth position and ensure adequate fixation over the entire immobilization period, achieving rigidity or flexibility, according to the type of trauma.

In light of these requirements, Schuchardt splints cannot be recommended, because they traumatize surrounding tissue and hinder optimal hygiene, which is an important precondition to healing (6, 18, 20, 24). Composite splints such as CS 1–4, wherein resin composite is applied approximally after conditioning with phosphoric acid, are difficult to remove and may break during the immobilization period. The creation of bracket splints requires special materials, and these splints present challenges to optimal oral hygiene. Wire-composite splints as well as the TRS and TTS fulfill most of the demands for splinting after dental trauma (5, 6, 15, 16, 18–20, 27). The advantage of wire-composite splints is that the required materials are cheap and usually available in dental offices (15, 20).

Differences in splint effect

All mean PTVpre showed variation across the results for each tooth before splint insertion; the standard deviations were larger for injured, loose teeth vs uninjured teeth. To control for these differences when evaluating splint effects, PTVpre was used as a covariate (14, 25).

For injured teeth, nearly all of the splints produced significant changes in tooth mobility in both the horizontal and vertical dimensions.

The rigidity of the splints varied across a wide range. For injured teeth, the largest horizontal and vertical splint effects were observed using the composite splints, followed by the TRS and WCS 3; such that there was almost no or low possible tooth mobility after immobilization. The smallest splint effects were achieved using the WCS 1, TTS, and WCS 2, with which little reduction of mobility was detected.

Based on these findings, the composite splints, the TRS, and the WCS 3 can be classified as rigid splints and the WCS 1, WCS 2, and TTS as flexible splints.

Filippi (17) evaluated the splint rigidity of different dental trauma splints *in vitro* using an acrylic model, and von Arx et al. (19) performed testing *in vivo* using uninjured volunteers. According to our findings, the conclusion of both studies is that tooth mobility change is higher when splinting with TRS and BS than using flexible WCS and TTS.

Methodological factors

There are a variety of models with which to evaluate splint rigidity, each of them having advantages and disadvantages. Oikarinen (24) and Filippi (17) used commercially available acrylic resin models. Tooth mobility was manipulated by placing silicon rubber pieces between the root and alveolar socket, and the teeth were fixed with apical screws. Unlike with natural enamel, it is not possible to use acid etching to improve adhesion (23) between the tooth surface and the resin composite. Furthermore the absence of the periodontal ligament could be considered a disadvantage.

Oikarinen et al. (14) and Berthold (25) tested splint rigidity using dissected sheep mandibles. The advantages of this approach are the presence of a periodontal ligament and natural enamel. The form, size, and crown-root relationship of sheep incisors are similar to those of human teeth, but sheep incisors are especially loose. Other possible disadvantages are the potential risk of Mad Cow Disease infection and the extensive variability between specimens.

von Arx et al. (19) performed rigidity testing on human volunteers with uninjured teeth. Advantages of this approach are the ability to bond splints to human enamel and the presence of a periodontal ligament. However, the potential for damage to the enamel during splint removal and the absence of traumatically loosened teeth can be considered disadvantages.

In our investigation, we used one acrylic resin model for reasons of easy handling and low variability. To improve adhesion between acrylic teeth and the composite used for splinting, we roughened the tooth surface. The periodontal ligament was simulated by placing a soft silicon layer between the root surface and the alveolar socket.

Methods for measuring tooth mobility include the evaluation of tooth movement under application of a defined load (24, 28, 29), use of the Mühlemann periodontometer (14), and use of the Periotest device (15, 17, 19, 25). The Periotest method is a well established and accepted technique for measuring tooth mobility in both periodontology (30–34) and dental traumatology (15, 17, 19, 25, 35–37). The advantages of this method are easy application, the ability to measure both horizontal and vertical dimension, and highly reproducible results (14).

Conclusion

According to the guidelines of IADT (21, 22) and within the limits of an *in vitro* study, we conclude that flexible or semirigid splints such as the WCS 1 and WCS 2 and the TTS are appropriate for splinting teeth with dislocation injuries and root fractures in the middle or apical part, whereas rigid splints such as the WCS 3 and TRS can be used for treating alveolar process fractures and infraalveolar root fractures in the cervical part.

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