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Impact of extracorporeal shockwave therapy on tooth mobility in adult orthodontic patients: a randomized single-center placebo-controlled clinical trial

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The protocol was registered at ClinicalTrials.gov of the U.S. National Institutes of Health.

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Abstract

Aim: This RCT investigated the effect of non-invasive extracorporeal shockwaves on tooth mobility in orthodontic patients after active treatment.

Materials and methods: Seventy-two adult patients were included in the study. Immediately after active orthodontic treatment, patients were assigned to a treatment or a placebo group based on block randomization. The orthodontic patients were required to be otherwise healthy. The region of interest was the anterior portion of the mandible. The treatment group received a single shockwave treatment with 1000 impulses while the placebo group was treated with an acoustic sham. Tooth mobility was evaluated over a period of 6 months using a Periotest and manual testing. Pocket probing depths, bleeding on probing and the irregularity index were also assessed.

Results: Tooth mobility reduced significantly over 6 months in both groups, but shockwaves achieved significantly more rapid reduction on manual testing. Probing depth was significantly reduced while the irregularity index remained stable. Bleeding on probing was significantly reduced in the treatment group. No anti-inflammatory effect could be derived due to possible initial group differences.

Conclusions: The mobility of teeth aligned by orthodontic treatment reduces over time. Shockwave treatment appeared to reduce tooth mobility more rapidly.

Key words: orthodontic; periotest; probing depth; shockwaves; tooth mobility

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Conflict of interest and source of funding statement

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Dr. Wolfgang Schaden is a shareholder at Tissue Regeneration Technology (TRT), Atlanta, Georgia, USA, and owner of the patent "Shockwaves stimulating biological tissue to regenerate".

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Orthodontic treatment activates the inflammatory cascade in alveolar bone and thus causes tooth movement (Meikle 2006). Orthodontists are well aware of the inflammatory cascade in action and the crucial importance of avoiding additional inflammation and damage to gingival tissue (Naranjo et al. 2006, van Gastel et al. 2008, 2011, Karkhanechi et al. 2013). In view of the fact that tooth mobility (TM) is increased after active orthodontic treatment, the purpose of retention in this setting is to avoid tooth movement (Watted et al. 2001). Full rehabilitation of the dentoalveolar apparatus takes more than 12 months (Sallum et al. 2004, Gkantidis et al. 2010, van Gastel et al. 2011). The risk of relapse of anterior crowding, especially in the mandible, is high. Long-term retention will be needed to stabilize the results of treatment (Blake & Bibby 1998, Edman Tynelius et al. 2010, Okazaki 2010, Thickett & Power 2010, Jaderberg et al. 2012).

Tooth mobility (TM) is an important parameter when assessing the periodontal condition of teeth. It is an indirect indicator of the functional condition of the periodontium (Giargia & Lindhe 1997). The health of the periodontal ligament is a main issue in periodontology and orthodontics. Periodontal inflammation, bone loss and reduced bone mineral density increase TM (Schulte et al. 1992, Winkler et al. 2001, Singh et al. 2012). In traumatology, TM is assessed regularly when monitoring splint therapy and for diagnosing tooth ankylosis (Mackie et al. 1996, Schulz et al. 2000, Campbell et al. 2005, Berthold et al. 2010). Occlusal interferences may also influence TM to a varying extent (Ishigaki et al. 2006, Jorge et al. 2007). TM was measured during comprehensive orthodontic treatment and in the retention period (Gruber 1990, Levander & Malmgren 2000, Watted et al. 2001, Tanaka et al. 2005, Jonsson et al. 2007, Liou et al. 2011). TM is assessed manually and digitally by the application of force to the crown of the tooth. Various devices were used in the past for this purpose. Currently the Periotest method is regarded as an objective and highly reproducible measurement (Rosenberg et al. 1995, Andresen et al. 2003, Berthold et al. 2010, 2011, Goellner et al. 2013). The Periotest measures the damping capacity of the periodontium, which involves fibres, blood vessels, nerves, cells and interstitial fluid transmitting force to the alveolar bone. The state of the periodontium, the amount of dentoalveolar bone and the length of the root are determining factors of TM (Giargia & Lindhe 1997, Levander & Malmgren 2000, Jonsson et al. 2007). Physiological tooth eruption, pathological impact such as trauma or inflammation, and also orthodontic tooth movement induced iatrogenically tend to aggravate TM. In contrast, reduced TM may be caused by root ankylosis, removal of occlusal premature contacts, or periodontal therapy (Giargia & Lindhe 1997, Goellner et al. 2013).

Extracorporeal shockwave therapy (ESWT) is an innovative method for reducing tooth mobility and rehabilitating adjacent tissues. Shockwaves are focused on alveolar bone and interfuse soft tissues (silicone membrane of the applicator, skin, cheek, gingiva) and liquids (water, sonic gel liquid, saliva) almost without any loss of energy (Thiel 2001, Schaden et al. 2007, Hazan-Molina et al. 2012). In an animal study, Wang et al. observed ESWT-associated differentiation of mesenchymal stem cells through superoxide-mediated signal transduction and vascularization of the bone-tendon junction (Wang et al. 2002a). ESWT activates osteoprogenitor cells in bone marrow and also their differentiation into osteoblasts through the induction of TGF-β (Wang et al. 2002b). ESWT stimulated bone healing at the early stage of 1 week after osteotomy (Wang et al. 2008). When mandibular distraction was performed in a rat model, ESWT was found to stimulate bone regeneration, presumably along with up-regulation of neovascularization, cell proliferation and osteogenic growth factor expression in the bone microenvironment (Lai et al. 2010). The mode of action involves osteogenesis, angiogenesis and revascularization. Local and systemic molecular and cellular effects have not yet been fully investigated (Wang et al. 2003, Ma et al. 2007, Yip et al. 2008). The effect of ESWT has been studied in periodontology. In animal models, ESWT was found to exert microbicidal effects on Streptococcus mutans and Porphyromonas gingivalis, induce bone regeneration after artificial trauma, while a plaque- and calculus-breaking effect was registered in an in vitro experiment (Novak et al. 2008, Sathishkumar et al. 2008, Muller et al. 2011).

The objective of the present study was to investigate the effect of extracorporeal shockwaves on tooth mobility after orthodontic alignment of teeth. The null hypothesis was that shockwaves do not influence tooth mobility in this setting.

Material and Methods

Trial design

This single-centre, randomized, placebo-controlled trial was approved by the institutional review board (EK1065/2010) and the protocol was registered at ClinicalTrials.gov of the U.S. National Institutes of Health.

Participants, eligibility criteria and setting

All study participants provided informed consent; women underwent a pregnancy test (Femtest, Omega-Teknika, Dublin, Ireland). Healthy patients who had undergone completed orthodontic treatment with fixed appliances were included in the study. The lower anterior teeth responded positively to sensitivity testing (Endo cold spray, Henry Schein Inc., Melville, NY, USA), percussion and palpation, had undergone no restorative treatment or trauma and had no periapical radiolucency. The fixed orthodontic appliance was a self-ligating bracket system (Smartclip 0.022 inch slot, 3M Unitek, Monrovia, CA, USA) with a 0.018×0.025 inch stainless steel archwire (SDS-Ormco, Glendora, CA, USA) ligated for 3 months. The appliance was removed and tooth surfaces were carefully inspected for adhesive remnants before starting the measurements. The patients wore an individualized passive retention aligner (Duran 1 mm, Scheu-Dental GmbH, Iserlohn, Germany) for 24 h over a period of 3 months, and at night for a further 3 months in order to reduce the risk of early relapse.

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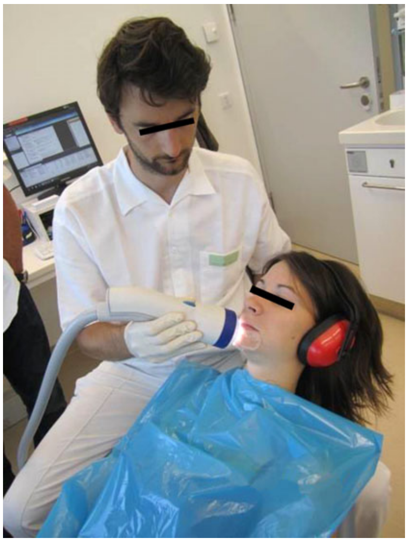

Fig. 1. Application of extracorporeal shockwave treatment.

Interventions

A single shockwave treatment (Fig. 1) with 1000 impulses at an energy flux density of 0.19–0.23 mJ/mm^2, with a pulse rate of five pulses per second, was applied in the treatment group, using a focused shockwave device (Orthogold 100, MTS/TNT Konstanz, Germany) (Sathishkumar et al. 2008, Hazan-Molina et al. 2012). All subjects received topical anaesthesia (xylocaine 2% gel, Astra-Zeneca Company, Vienna, Austria) in the vestibular mucosa, between the lower right and left canine. Sonic gel liquid (Gerasonic, Gerot Pharmazeutika Company, Vienna, Austria) was applied to the soft tissue between the chin and the lower lip as conduction medium. An ear protector was used to reduce acoustic disturbance. Patients in the placebo group were treated with an acoustic sham of the extracorporeal shockwave using the same pulse rate, volume level and treatment time. The shockwave applicator was used in deactivated form and in the same manner as in the treatment group.

Tooth mobility testing of the lower anterior teeth was performed by one operator (FF) in two steps. First the Periotest device (Periotest classic, Medizintechnik Gulden, Moldautal, Germany) was used to determine TM in Periotest values (PTV); this was done twice for each tooth. The disinfected and calibrated Periotest applicator was positioned according to the manufacturer's instructions, in the centre of the crown, with a horizontal distance of 2 mm and at a 90° angle to the long axis of the tooth. The subjects were asked to remain in relaxed upright sitting position. Manual TM testing was then performed twice by fixing and pushing each tooth crown using the shafts of two dental instruments, according to Miller′s classification (Miller 1950). Analysis was performed perpendicular to the tested tooth. Both measurements were conducted on the day of bracket removal and after 1, 2, 4 and 6 months.

The parameters pocket probing depth (PPD) and bleeding on probing (BOP) were evaluated on the day of bracket removal and 6 months later using a calibrated periodontal probe (ClickProbe®, KerrHawe SA, Bioggio, Switzerland) on three buccal and lingual (distal, middle, mesial) locations of the lower anterior teeth.

The irregularity index, representing anterior tooth displacement, was assessed on dental casts at the beginning and the end of the study. The linear displacement of the anatomic contact points of each mandibular incisor from the adjacent tooth contact point was measured with a digital measuring gauge *(Little 1975)*.

Outcomes (primary and secondary) and changes after commencement of the trial

The primary outcome measure was the TM of the lower anterior teeth while secondary outcome measures were PPD, BOP and the irregularity index of the lower anterior teeth; these values were saved digitally in a computer (MacBook Pro, Apple Inc., Cupertino, CA, USA).

Sample size calculation

Calculation was based on two groups of 25 participants each, which yielded a difference of 0.8 standard deviation between groups with 80% power, and an alpha of 0.05 by a two-sided t-test. This corresponds to a difference of 5.3 PTV according to Gruber et al. (Gruber 1990).

Interim analyses and stopping rules

Not applicable.

Randomization (random number generation, allocation concealment, implementation)

Block randomization (size 4) was used to allocate patients to the treatment or placebo, using digital randomization software (Randomizer, version 1.8.1, Institute for Medical Informatics, Statistics and Documentation, Medical University of Graz, Austria). The random allocation sequence was printed and sealed in envelopes with the participant's initials and age on the outside. The envelopes were locked until the start of treatment. This procedure was performed and monitored by one operator (DB).

Blinding

Blinding was performed for the subjects as described, and for the outcome assessor (DK). Blinding of the shockwave therapist (RK) was not performed. The results of the measurements were coded by one operator (RM) for the outcome assessor to ensure blinding.

Statistical analysis (primary and secondary outcomes, subgroup analyses)

A linear mixed effects model was calculated separately for TM calculations of the PTV and for manually determined values. The fixed effect of main interest was the interaction of time and treatment (treatment

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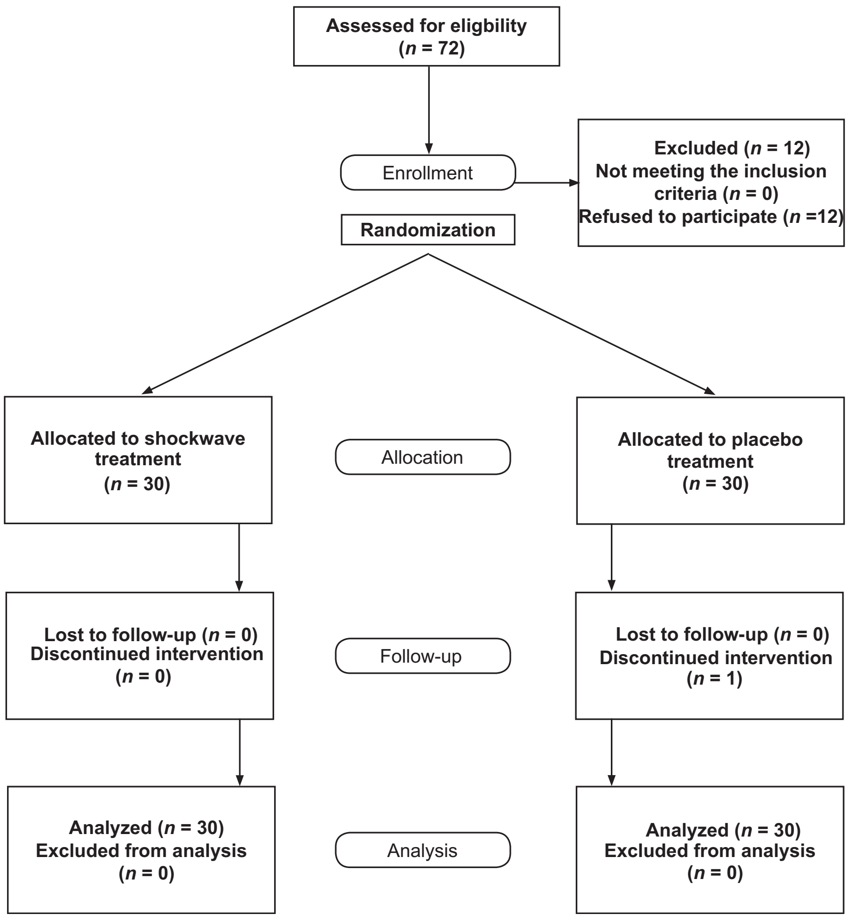

Fig. 2. Flow chart showing the allocation of participants and follow-up during the investigation.

Table 1. Baseline demographics, tooth mobility, periodontal parameters and irregularity index of placebo (PC) and treatment (T) group

	PC	T
Sample size (*n*)	30	30
Male gender (%)	11 (36)	15 (50)
Age ± SD (years)	25.9 ± 8.1	27.9 ± 7.5
Periotest (PTV)	8.8 ± 6.2	8.0 ± 5.4
TM	1.28 ± 0.7	1.36 ± 0.64
PPD (mm)	1.27 ± 0.54	1.25 ± 0.5
BOP (%)	31	29
Irregularity index (mm)	0.57 ± 0.52	0.43 ± 0.31

effect per month). Other fixed effects included in the model were time, treatment, tooth morphotype (canine, lateral and central incisor), gender and age, while the effect of the patient was modelled as a random effect. The analysis of the binary response BOP was based on a generalized linear mixed effects model, which was adjusted for time, treatment effect, age and gender. Again, each individual was modelled as a random effect.

Hypothesis testing for all mixed effect models was performed using Wald tests. A correlation test was used for the two mobility measurements, based on Pearson's correlation coefficient. Furthermore, a linear model was fitted to test the effect of treatment, gender and age on PPD and the irregularity index. *p*-values of primary tests (treatment effect on TM) were Bonferroni-adjusted to correct for multiplicity. *p*-values of 0.05 or less were considered significant. All calculations were performed in R 3.0.2.

Results

Participant flow (include flow diagram and time periods)

Initially 72 persons were enrolled in the clinical study; 12 subjects declined participation immediately prior to treatment. One patient missed the second and fourth investigation appointment during the observation period (Fig. 2). Recruitment was started in April 2011 and spanned a period of 2 years. The investigation was started in October 2011 and concluded 2 years later.

Baseline data (include baseline table)

Patient characteristics are shown in Table 1. The overall mean age was 26.9 years (SD 7.8 years, range 18–49 years), with a predominance of the female gender (women 57%, men 43%).

Numbers analysed for each outcome (estimation and precision, subgroup analyses)

Mean PTV and the corresponding confidence intervals for the canines, lateral and central incisors are shown in Fig. 3A. The estimated Periotest coefficients for the variables of the mixed model are presented in Table 2. At baseline the estimated mean difference between the placebo group and the treatment group was 1.09 (no significant difference, $p = 0.0910$). The PTV decreased significantly during the observation period in both groups ($p < 0.0001$), but remained unaffected by treatment ($p = 0.4192$). Tooth morphotype significantly influenced the PTV. The estimated mean differences were 3.42, 8.85 and 5.43 for central-lateral, central-canine and lateral-canine ($p < 0.0001$ for all three comparisons). PTV did not depend on the gender of the patients, but the model indicates that PTV increased with age.

Mean manual TM values and corresponding confidence intervals of

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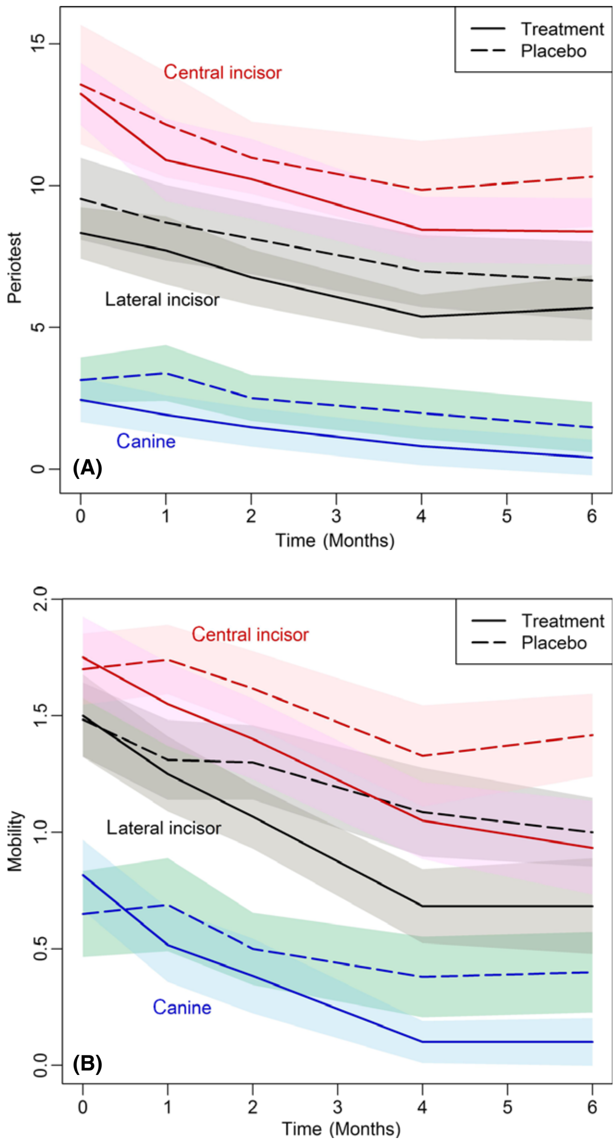

Fig. 3. (A) Mean Periotest values (PTV) during the six-month observation period in the treatment (T) and the placebo (PC) group for the central, lateral incisors and canines, including the 95% confidence intervals (shown in pale colour). (B) Mean mobility values during the 6-month observation period in the treatment (T) and the placebo (PC) group for the central, lateral incisors and canines, including the 95% confidence intervals (shown in pale colour).

the canines, lateral and central incisors are shown in Fig. 3B. The results of the linear mixed effects model for the mobility values are presented in Table 3. Again, the mean difference between the treatment group and the placebo group was not significant at baseline (p = 0.8027). Mobility values for all patients decreased significantly during the observation period (p < 0.0001), but mobility values for patients receiving treatment decreased even more rapidly. The additional treatment effect per month is estimated to be −0.067 (p < 0.0001). As for PTV, the significance with respect to age was slightly below the significance level. Gender, in contrast, was not significant.

Analysis of PTV and mobility values produced similar results. The test for correlation showed a strong correlation between the two outcome parameters (95% CI 0.5520–0.6132; p-value < 0.0001).

The results of the linear model indicate that no parameter (treatment, gender or age) significantly affects the irregularity index or PPD (Table 4A, B). Both global F-tests – for the irregularity index (p = 0.2674) and for PPD (p = 0.2358) – were not significant. However, PPD still decreased significantly during the observation time (p = 0.0002) while the irregularity index remained constant (p = 0.6085). In the placebo group PPD decreased from 1.27 ± 0.54 mm to 1.12 ± 0.35 mm and in the treatment group from 1.25 ± 0.5 mm to 1.09 ± 0.31 mm. BOP decreased significantly in the treatment group (p < 0.0001). In the placebo group BOP decreased from 30% to 28% and in the treatment group from 29% to 14%. Age and gender had no significant impact on this parameter (Table 4C).

Harmful effects

No unintended pernicious effects occurred after ESWT during the entire study period. The shockwaves did not alter the patients' sensitivity or acoustic perception.

Discussion

Extracorporeal shockwaves have been found to exert beneficial effects on tissue regeneration. Owing to their potential for bone regeneration, extracorporeal shockwaves may also reduce tooth mobility during the orthodontic retention phase (Sathishkumar et al. 2008, Wang et al. 2008, Lai et al. 2010). The proven microbicidal effect of shockwaves may additionally enhance periodontal tissue regeneration (Novak et al. 2008). In the present in vivo study we investigated the effect of extracorporeal shockwaves on TM.

Main findings in the context of existing evidence – interpretation

An objective assessment of TM by the Periotest device showed a significant reduction over time in both groups. No statistically significant difference was found between the treatment and the placebo group. The PTV of the lower anterior teeth at the beginning of treatment and during the retention phase were in accordance with the values reported in the recent published literature

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Table 2. Wald tests for fixed effects of Periotest measurement

Variable	Coefficient	Standard error	*p*-value
Intercept (PTV)	9.3461	1.1583	<0.0001
Time	−0.4429	0.0470	<0.0001
Treatment group	−1.0885	0.6346	0.0910
Treatment effect/month	−0.0834	0.0664	0.4192*
Central *versus* Lateral incisor	−3.4211	0.1755	<0.0001
Canine *versus* Central incisor	−8.8490	0.1755	<0.0001
Canine *versus* Lateral incisor	−5.4279	0.1755	<0.0001
Male	−0.5360	0.6129	0.3855
Age	0.1295	0.0394	0.0017

*Bonferroni-adjusted to correct for multiplicity.

Table 3. Wald tests for fixed effects for manual TM measurement

Variable	Coefficient	Standard error	*p*-value
Intercept (TM)	1.5110	0.1312	<0.0001
Time	−0.0647	0.0081	< 0.0001
Treatment group	−0.0187	0.0744	0.8027
Treatment effect/month	−0.0673	0.0114	<0.0001*
Central *versus* Lateral incisor	−0.3121	0.0303	<0.0001
Canine *versus* Central incisor	−0.9950	0.0303	<0.0001
Canine *versus* Lateral incisor	−0.68289	0.0303	<0.0001
Male	−0.1221	0.0685	0.0799
Age	0.0096	0.0044	0.0343

*Bonferroni-adjusted to correct for multiplicity.

Table 4. (A) *T*-tests for effects on periodontal probing depth (mm). (B) *T*-tests for effects on the irregularity index (mm). (C) Wald tests for fixed effects on bleeding on probing

Variable	Coefficient	Standard error	*p*-value
(A)			
Intercept (Time)	−0.2512	0.0671	0.0002
Male	0.0575	0.0359	0.1107
Treatment	−0.0299	0.0358	0.4037
Age	0.0032	0.0023	0.1666
(B)			
Intercept (Time)	−0.0972	0.1887	0.6085
Male	−0.0125	0.1009	0.9016
Treatment	−0.1054	0.1005	0.2989
Age	0.0117	0.0065	0.0773
	Estimate	Standard error	*p*-value
(C)			
Intercept	−0.9447	−0.9447	<0.0001
Time	−0.0622	0.0826	0.4515
Male	0.0417	0.0719	0.5619
Treatment	−0.9227	0.1122	<0.0001
Age	0.0025	0.0046	0.5926

(Gruber 1990, Watted et al. 2001, Tanaka et al. 2005, Liou et al. 2011). The values achieved at 6 months of retention did not change during the following 18 months. However, the PTV of orthodontic patients were higher than those of persons who had undergone no orthodontic therapy and had healthy periodontal conditions (Schulte et al. 1992, Winkler et al. 2001, Ishigaki et al. 2006).

The different morphotype and root size of the anterior teeth may account for the significant difference in TM (Schulte et al. 1992, Levander & Malmgren 2000, Watted et al. 2001, Tanaka et al. 2005, Ishigaki et al. 2006, Jonsson et al. 2007).

Gender had no significant influence on the quantity or reduction of PTV. This is in agreement with data reported by Tanaka et al. (2005); Ishigaki et al. (2006). However, Singh et al. found higher PTV in women during menopause, with lower bone density (Singh et al. 2012).

In the present investigation age was found to exert a significant impact on TM; the latter increased with age. This positive correlation obviously does not concur with data reported by other investigators in growing patients (Mackie et al. 1996, Campbell et al. 2005, Tanaka et al. 2005). The greater TM in our study may have been due to alveolar bone loss in aged persons (Schulte et al. 1992, Giargia & Lindhe 1997).

Miller‘s manual TM test revealed a more rapid decrease of TM during the retention phase. Gender exerted no significant impact on TM. This was in contrast with age which correlated positively, as observed for PTV. As manual TM testing is prone to subjective evaluation, the results should be viewed with particular caution (Jorge et al. 2007). A strong correlation between PTV and manual TM testing was also registered by Göllner et al. (Goellner et al. 2013). Rosenberg found a strong correlation in the presence of high TM values (Rosenberg et al. 1995). Despite this correlation, only manual TM testing revealed a statistically faster reduction of TM. The potential regenerative effect of ESWT on bone may be positive on manual testing, especially when the tester is blinded and feels subjectively restrained when trying to move the instrument. Besides, in the present study a subjective method was compared with an objective method. The latter might show a higher TM compared to the TM registered on clinical investigation.

Only a minimal decrease in TM was noted after 4 months, indicating completion of periodontal remodelling of collagenous fibres. This finding contradicts the proposition of long-term retention over 1 year (Gkantidis et al. 2010).

The assessment of PPD showed a significant decrease during the observation phase, unaffected by shockwaves, age or gender. This is confirmed by Sallum et al. and Van Gastel et al., who also did not

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observe as much PPD as they did at baseline (Sallum et al. 2004, van Gastel et al. 2011). It may be speculated that increasing PPD, plaque accumulation and bleeding during orthodontic treatment are responsible for this phenomenon (van Gastel et al. 2008, Karkhanechi et al. 2013). Naranjo et al., who investigated the same aspects, found no difference in PPD during orthodontic treatment despite increased plaque accumulation and bleeding (Naranjo et al. 2006).

Bleeding on probing was reduced significantly in the treatment group only in the present study. Shockwaves seemed to exert anti-inflammatory and regenerative effects in an animal model (Sathishkumar et al. 2008). As orthodontic patients are required to be plaque free to facilitate orthodontic therapy, no plaque measurement was performed in this study. The difference in BOP between both groups could therefore be due to the possibility that plaque levels could have been higher in the control group. It may be speculated that the plaque-breaking and microbicidal effect of ESWT reduced plaque accumulation to a greater extent than in the placebo group (Sallum et al. 2004, Naranjo et al. 2006, Novak et al. 2008, van Gastel et al. 2011, Muller et al. 2011, Karkhanechi et al. 2013). Thus, no direct anti-inflammatory effect may be concluded out of a single shock wave application.

The assessment of tooth displacement by the irregularity index showed no significant difference between groups. The patients' age and gender did not influence this parameter during the observation period. The same has been observed in other clinical studies testing different retention materials (Little 1975, Edman Tynelius et al. 2010, Thickett & Power 2010, Jaderberg et al. 2012). The severity of the irregularity of tooth position before orthodontic treatment exerts a significant impact on relapse rates in aligned teeth (Okazaki 2010). The retention material used and the protocol appeared to be sufficient for tooth stabilization.

Initially the study was planned without the use of local or regional anaesthesia. Therefore, the lowest energy flux densities with osteogenic potential were chosen. The achievement of significant differences in future studies might necessitate higher energy flux densities and pulses. As we used an electrohydraulic device, a single treatment – as used in previous studies – was sufficient (Furia et al. 2010, Stojadinovic et al. 2011).

If future studies were to establish the benefits of using ESWT for dental pathologies, the procedure may well enter clinical routine. Apart from the cost of the device (25,000–50,000 Euros), the cost of refurbishment - depending on the technology used - is negligible. The duration of treatment is about 10 min.

Limitations

Plaque and the gingival index could not be assessed in combination with fixed orthodontic appliance in situ at the beginning of the study. Furthermore, we used ESWT in the mandible only. The quality of bone and soft tissue characteristics are different in the maxilla, which may influence TM.

Generalizability

The applicability of the findings may be limited by the single-centre design of the study. Besides, it may be speculated that multiple applications or higher energy flux densities of shockwaves would reduce TM to a greater extent. At this moment and on the basis of the results, ESWT as an adjunct for periodontal or orthodontic treatment is still far from being recommended for routine clinical use as neither the optimal dose nor the number of application are clear. In addition, the cellular mechanisms that might be involved in the proposed effects are far from being understood.

Conclusions

The TM of orthodontically aligned teeth decreased over time, depending on the tooth morphotype and the patient's age.

Shockwave treatment appeared to reduce TM faster. An anti-inflammatory effect could not be directly derived from a reduced BOP between the two groups.

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Clinical Relevance

Scientific rationale for the study: Orthodontists are confronted with tooth retention after active treatment because tooth mobility increases after orthodontic treatment. Extracorporeal shockwaves were found to exert regenerative effects on tissue in the in vitro setting. Shockwaves may be beneficial in the rehabilitation of teeth with high mobility and the surrounding gingival tissue during retention.

Principal findings: Reduction of tooth mobility during retention with an alleged anti-inflammatory effect.

Practical implications: The in vivo data obtained in the present study confirm those from in vitro and animal studies. Reduced tooth mobility may lead to a refined retention protocol after orthodontic treatment.

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