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# A randomised clinical trial of the effectiveness of 0.018-inch and 0.022-inch slot orthodontic bracket systems: Part 3. Biological side effects of treatment

## SUMMARY

**Objective:** To compare orthodontically induced inflammatory root resorption (OIIRR) and patient perception of pain during orthodontic treatment between 0.018-inch and 0.022-inch slot bracket systems.

**Subjects and methods:** Eligible participants aged 12 years or over were allocated to treatment with the 0.018-inch or 0.022-inch slot MBT appliance (3M-Unitek, Monrovia, California) using block randomisation in groups of ten. OIIRR was assessed radiographically using standardised periapical radiographs before and after 9 months from the start of treatment. Patient perception of pain was assessed using a validated patient questionnaire at 6 months from the start of treatment. Parametric tests (t-test) and non-parametric tests (Chi-square with Fisher's exact tests and Kruskal-Wallis test) assessed differences between the groups ( $P < 0.05$ ). The correlation between severity of OIIRR and abnormal root morphology, history of dental trauma, and pain during treatment was assessed.

**Results:** Of the 187 participants randomised (1:1 ratio), 34 withdrew or were excluded (protocol deviations or poor cooperation). There were 77 patients in the 0.018-inch slot group and 76 patients in the 0.022-inch slot group (overall mean age: 19.1 years). Baseline characteristics were similar between groups ( $P > 0.05$ ). There was no significant difference in the severity of the OIIRR nor patient perception of pain between the two study groups ( $P=0.115$  and  $P=0.08$  respectively). The correlation between the severity of OIIRR and abnormal root morphology or history of dental trauma was not statistically significant ( $P=0.086$  and  $P=0.313$ ). Moreover, there was no significant correlation between the severity of OIIRR and pain during treatment ( $R=0.045$ ,  $P=0.617$ ).

**Limitations:** It was impossible to blind clinicians or patients to allocation and oral hygiene and periodontal outcomes were not assessed.

**Conclusions:** The effect of bracket slot size on the severity of OIIRR and patient perception of pain is not significant.

**Conflict of interest:** The authors declare no conflict of interest.

**Registration:** The trial was registered with ClinicalTrials.gov on 5<sup>th</sup> March 2014, registration number: NCT02080338.

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## INTRODUCTION

There are several fixed appliance systems used in contemporary orthodontics which include multiple preadjusted edgewise fixed appliance systems. The orthodontic clinicians are divided around the world regarding preferences for the 0.018-inch or 0.022-inch slot size pre-adjusted edgewise

bracket systems {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1043/0003-3219(2002)072<0001:barodb>2.0.co;2", "ISBN" : "0003-3219", "ISSN" : "00033219", "PMID" : "11843268", "abstract" : "In recent issues of this journal, Rubin 1 and Peck 2 extolled the virtues of standardization to a single universal slot size for all orthodontic brackets. They wrote about advantages of using only a single bracket dimension. The benefits and rationale of using both the currently manufactured 0.018-inch and 0.022-inch slot sizes within a single bracket system were not explored. Differential slot size treatment uses two different slot sizes within the same appliance setup and is the foundation of bidimensional treatment. Schudy and Schudy 3 first proposed the amalgamation of two different slot sizes within an individual treatment appliance with their bimetric system, and the amalgamation was later proposed by Gianelly et al 4 with their bidimensional technique. In its current form, 0.018-inch brackets are placed on maxillary and mandibular central and lateral incisors, and 0.022-inch brackets are placed on canines and posterior teeth and incorporated into each setup. The two slot sizes represent a different set of distinct advantages to treatment mechanics. The 0.022-inch system offers more options in archwire size selection. 5,6 With the use of undersized archwires, one can facilitate the free sliding of the archwire through the bracket slot. This provides a system with less frictional resistance or binding at the bracket wings. Being able to use larger diameter archwires for treatment mechanics also has benefits. Larger dimension archwires provide increased stiffness and facilitate keeping teeth upright during space closure and retraction mechanics. Conversely, a distinct disadvantage may be encountered when filling the bracket slot. Full-sized stainless steel rectangular archwire becomes markedly reduced in springiness and range, thereby severely limiting the ability to place effective torque and finishing bends. The 0.018-inch system provides a contrasting set of benefits. Although there may be fewer choices in arch wire dimensions, filling the bracket slot is more easily accomplished. The capacity to fill the bracket slot allows for a greater use of the program or prescription built into the bracket. With the introduction of preadjusted appliances, the focus has moved to customization of brackets to affect specific and exact positioning of the dentition. Previously, the orthodontist relied on modifications in the archwire in the form of first-, second-, and third-order bends to detail the teeth. Preadjusted appliances build corrections directly, "author" : [ { "dropping-particle" : "", "family" : "Epstein", "given" : "Martin B.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Epstein", "given" : "Joshua Z.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "Angle Orthodontist", "id" : "ITEM-1", "issue" : "1", "issued" : { "date-parts" : [ [ "2002" ] ] }, "page" : "1-2", "title" : "Benefits and rationale of differential bracket slot sizes: the use of 0.018-inch and 0.022-inch slot sizes within a single bracket system.", "type" : "article", "volume" : "72" }, "uris" : [ "http://www.mendeley.com/documents/?uuid=bc1e4c6f-e89e-48f4-9b67-302be687268b" ] } ], "mendeley" : { "formattedCitation" : "(1)", "plainTextFormattedCitation" : "(1)", "previouslyFormattedCitation" : "(1)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" }. Various theories of biomechanics are applied during different stages of the orthodontic treatment depending on the treatment objectives and operator preference. The proposed difference in the biomechanical interaction in both the 0.018-inch and 0.022-inch bracket slot systems and their archwires may influence the effectiveness of the different stages of orthodontic treatment {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1043/0003-3219(1991)061<0293:COTFCF>2.0.CO;2", "ISBN" : "0003-3219 (Print)\r0003-3219 (Linking)", "ISSN" : "00033219", "PMID" : "1763840", "abstract" : "Coefficients of friction were evaluated in the dry and wet (saliva) states for stainless steel, cobalt-chromium, nickel titanium, and beta-titanium wires against either stainless steel or polycrystalline alumina brackets. For both operators' experiments, an 0.010" stainless steel ligature wire pressed each archwire into the 0.018" or 0.022" bracket slot at 34 degrees C. In the dry state and regardless of slot size, the mean kinetic coefficients of friction were smallest for the all-stainless steel combinations (0.14) and largest for the beta-titanium wire combinations (0.46). The coefficients of the polycrystalline alumina combinations were generally greater than the corresponding combinations that included stainless steel brackets. In the wet state, the kinetic coefficients of the all-stainless steel combinations increased up to 0.05 over the dry state. In contrast, all beta-titanium wire combinations in the wet state decreased to 50% of the values in the dry state. The mixed reports that saliva may promote adhesive and lubricious behaviors

may have some substance.", "author" : [ { "dropping-particle" : "", "family" : "Kusy", "given" : "R. P.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Whitley", "given" : "J. Q.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Prewitt", "given" : "M. J.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "Angle Orthodontist", "id" : "ITEM-1", "issue" : "4", "issued" : { "date-parts" : [ [ "1991" ] ] }, "page" : "293-302", "title" : "Comparison of the frictional coefficients for selected archwire-bracket slot combinations in the dry and wet states.", "type" : "article-journal", "volume" : "61", "uris" : [ "http://www.mendeley.com/documents/?uuid=da730cc9-f642-43dc-8877-341a076612ea" ] }, "mendeley" : { "formattedCitation" : "(2)", "plainTextFormattedCitation" : "(2)", "previouslyFormattedCitation" : "(2)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" }. The alignment of malpositioned teeth begins in the initial stages of orthodontic treatment and is accomplished with flexible round archwires generating a combination of labiolingual and mesiodistal tipping {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1038/sj.bdj.2012.829", "ISBN" : "978-0-323-04046-4", "ISSN" : "0889-5406", "PMID" : "11094367", "abstract" : "Now in full color, Contemporary Orthodontics, 4th Edition is a practical resource with a long tradition of excellence. Line drawings and more than 1,000 new color images illustrate concepts more clearly than ever. This book includes detailed information on diagnosis, treatment planning concepts, related problems or controversies, and current treatment procedures, including the role of orthodontics in comprehensive treatment of patients with multiple problems.A NEW full-color design includes a total of more than 1,400 clinical photographs and illustrations.Application of the \"soft tissue paradigm\" to modern orthodontic diagnosis and treatment planning. Critical evaluation of controversies in treatment approaches and treatment timing.NEW information on the use of cone beam CT for 3-dimensional evaluation of dental and facial dimensions and relationships, and 3-D superimpositions to evaluate treatment response.Problem-oriented treatment planning, with use of digital technology to develop a database that can feed through to the treatment plan.Updated content on biomechanics to help you plan efficient use of modern orthodontic appliance systems.NEW skeletal anchorage techniques using bone anchors and mini screws.Chapters on adult treatment featuring the sequencing of multidisciplinary treatment, the new approach to lingual orthodontics, and a discussion of surgical vs. orthodontic treatment options.Full-color design includes hundreds of clinical photographs and illustrations with brighter, more engaging text and more demonstrative figures.Diagnosis and treatment planning chapters are revised to consider new paradigms to teach students and orthodontists how to apply the results of current research to their practice and treatment plans.Current technologies and advances in contemporary treatment provide clinicians with ways to make treatment planning and execution more efficient.Updated content on biomechanics gives clinicians ways to plan appropriate orthodontic appliance systems through which mechanotherapy is delivered using principles of forces.Updated information on mechanical devices, such as transplants, transpositions, implants, and temporary anchorage using mini screws, provide an understanding on how these devices can affect orthodontic treatment and what is available on the market to improve treatment outcomes.Appliance chapters have been condensed to reflect only the most useful and contemporary materials.Chapters on treatment for adults have been r\u2026", "author" : [ { "dropping-particle" : "", "family" : "Proffit", "given" : "WR", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Fields", "given" : "HW", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Sarver", "given" : "DM", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "St Louis", "id" : "ITEM-1", "issued" : { "date-parts" : [ [ "2007" ] ] }, "number-of-pages" : "414-417; 611-612", "title" : "Contemporary Orthodontics", "type" : "book" }, "uris" : [ "http://www.mendeley.com/documents/?uuid=517a83b9-b9e8-4e8d-81b2-f981734e4371" ] }, "mendeley" : { "formattedCitation" : "(3)", "plainTextFormattedCitation" : "(3)", "previouslyFormattedCitation" : "(3)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" }. Rectangular archwires are almost always used at a later stage during alignment, to initiate torque control with rectangular stainless steel archwires used as working archwires during the space closure stage and correction of inter-arch relationships. The influence of treatment modalities on the effectiveness of

orthodontic treatment had been investigated in the literature {ADDIN CSL\_CITATION { "citationItems": [ { "id": "ITEM-1", "itemData": { "DOI": "10.1016/j.ajodo.2007.08.030", "ISBN": "1097-6752 (Electronic)\r0889-5406 (Linking)", "ISSN": "08895406", "PMID": "19732667", "abstract": "Introduction: Our objective was to compare the effects of 2 preadjusted appliances on angular and linear changes of the mandibular incisors, and transverse mandibular arch dimensional changes over a minimum of 30 weeks. This was a prospective, randomized, controlled, clinical trial at the Royal London Hospital, School of Dentistry, in London and the Kent and Canterbury Hospital in Canterbury, United Kingdom. Methods: Sixty- six consecutive patients satisfying the inclusion criteria were enrolled and randomly allocated to treatment with a self-ligating bracket system (SmartClip, 3M Unitek, Monrovia, Calif) and conventional preadjusted edgewise brackets (Victory, 3M Unitek). Initial study models and cephalograms were obtained within a month of starting the trial. All subjects received treatment with the following archwire sequence: 0.016-in round, 0.017 ?? 0.025-in rectangular, 0.019 ?? 0.025-in rectangular martensitic active nickel-titanium archwires, and 0.019 ?? 0.025-in stainless steel archwires. Final records, including study models and a lateral cephalogram, were collected a minimum of 30 weeks after initial appliance placement. Lateral cephalograms were assessed for treatment-related changes in mandibular incisor inclination and position. Transverse dimensional changes in intercanine, interpremolar, and intermolar dimensions, and the amount of crowding alleviated during the study period were assessed by comparison of pretreatment and posttreatment models. All measurements were made with a digital caliper (150 mm ISO 9001 electronic caliper, Tesa Technology, Renens, Switzerland). Results: Sixty patients completed the study. After adjustment for pretreatment values, duration of treatment, and amount of crowding alleviated during the study period, bracket type had little effect on incisor inclination (P = 0.437) and positional changes (P = 0.35), and intercanine (P = 0.967), inter-first premolar (P = 0.495), and inter-second premolar (P = 0.905) dimensions. However, the self-ligating appliance produced slightly more expansion in the molar region, a difference that was statistically significant (P = 0.009). Pretreatment values for incisor inclination (P = 0.044) and transverse dimensions (P = 0.000) affected inclination and transverse changes, respectively, with proclination less likely when the labial segment was proclined at the outset and expansion unlikely during leveling and alignment in wider arches. Greater alleviation of crowding during the stud\u2026", "author": [ { "dropping-particle": "", "family": "Fleming", "given": "Padhraig S.", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "DiBiase", "given": "Andrew T.", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Sarri", "given": "Grammati", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Lee", "given": "Robert T.", "non-dropping-particle": "", "parse-names": false, "suffix": "" } ], "container-title": "American Journal of Orthodontics and Dentofacial Orthopedics", "id": "ITEM-1", "issue": "3", "issued": { "date-parts": [ [ "2009" ] ] }, "page": "340-347", "title": "Comparison of mandibular arch changes during alignment and leveling with 2 preadjusted edgewise appliances", "type": "article-journal", "volume": "136" }, "uris": [ "http://www.mendeley.com/documents/?uuid=26d845f8-5164-403b-9efa-b5436fa97563" ] }, { "id": "ITEM-2", "itemData": { "DOI": "10.1016/j.ajodo.2008.04.018", "ISBN": "1097-6752 (Electronic)\n0889-5406 (Linking)", "ISSN": "08895406", "PMID": "18929262", "abstract": "Introduction: The aim of this study was to compare the efficiency of mandibular tooth alignment and the clinical effectiveness of a self-ligating and a conventional preadjusted edgewise orthodontic bracket system. Methods: A multicenter randomized clinical trial was conducted in 2 orthodontic clinics. Sixty-two subjects (32 male, 30 female; mean age, 16.27 years) with mandibular incisor irregularities of 5 to 12 mm and a prescribed extraction pattern including the mandibular first premolars were randomly allocated to treatment with Damon3 self-ligating (Ormco, Glendora, Calif) or Synthesis (Ormco) conventionally ligated brackets. Fully ligated 0.014-in nickel-titanium archwires were used first in both groups, followed by a sequence of 0.014 \u00d7 0.025-in and 0.018 \u00d7 0.025-in nickel-titanium, and 0.019 \u00d7 0.025-in stainless steel. Study casts were taken at the start of treatment (T1), the first archwire change (T2), and the placement of the final 0.019 \u00d7 0.025-in archwire (T3). Cephalometric lateral skull and long-cone periapical radiographs of the mandibular incisors were taken at T1 and T3. Results: No significant difference was noted (P >0.05) in initial rate of alignment for either bracket system. Initial irregularity influenced subsequent rate of movement, but sex, age, and appliance type were statistically insignificant. Alignment was associated

with an increase in intercanine width, a reduction in arch length, and proclination of the mandibular incisors for both appliances, but the differences were not significant. Incisor root resorption was not clinically significant and did not differ between systems. Conclusions: Damon3 self-ligating brackets are no more efficient than conventional ligated preadjusted brackets during tooth alignment. \u00a9 2008 American Association of Orthodontists.", "author": [ { "dropping-particle": "", "family": "Scott", "given": "Paul", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "DiBiase", "given": "Andrew T.", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Sherriff", "given": "Martyn", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Cobourne", "given": "Martyn T.", "non-dropping-particle": "", "parse-names": false, "suffix": "" } ], "container-title": "American Journal of Orthodontics and Dentofacial Orthopedics", "id": "ITEM-2", "issue": "4", "issued": { "date-parts": [ [ "2008" ] ] }, "title": "Alignment efficiency of Damon3 self-ligating and conventional orthodontic bracket systems: A randomized clinical trial", "type": "article-journal", "volume": "134" }, "uris": [ [ "http://www.mendeley.com/documents/?uid=ab95d3d4-820b-43cf-8385-4538edf42740" ] ] }, "mendeley": { "formattedCitation": "(4,5)", "plainTextFormattedCitation": "(4,5)", "previouslyFormattedCitation": "(4,5)" }, "properties": { "noteIndex": 0 }, "schema": "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" }} however, the influence of variation in the bracket slot system on the orthodontically induced inflammatory root resorption (OIIRR), and patient perception of pain during treatment remains to be investigated.

During orthodontic tooth movement, unwanted biological side effects can occur including OIIRR. It has been reported that OIIRR can be detected microscopically after 15 days {ADDIN CSL\_CITATION { "citationItems": [ { "id": "ITEM-1", "itemData": { "DOI": "10.1016/S0002-9416(70)90219-8", "ISBN": "0002-9416", "ISSN": "00029416", "PMID": "5265007", "abstract": "This report represents the first part of a study concerned with pulp and dentine reactions during tooth movement. The experimental material consisted of thirty-five intact teeth from children aged 10 to 13 years. These teeth were intruded with forces ranging from 35 to 250 Gm. with fixed appliances under controlled conditions for 4 to 35 days. All these teeth were extracted immediately after the force was removed. A similar number of untreated teeth served as controls. The main pulp changes in the experimental material included vacuolization of the pulp tissue and circulatory disturbances. Teeth with completed apices exhibited more severe changes than teeth with open apices, and the magnitude of the force was also important. In the teeth with incomplete root development, disturbances in the root formation frequently occurred. The resorption observed in dentine was related to the magnitude of the force and the duration of the experiment. ?? 1970 The C. V. Mosby Company.", "author": [ { "dropping-particle": "", "family": "Stenvik", "given": "A.", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Mj\u00f6r", "given": "I. A.", "non-dropping-particle": "", "parse-names": false, "suffix": "" } ], "container-title": "American Journal of Orthodontics", "id": "ITEM-1", "issue": "4", "issued": { "date-parts": [ [ "1970" ] ] }, "page": "370-385", "title": "Pulp and dentine reactions to experimental tooth intrusion. A histologic study of the initial changes", "type": "article-journal", "volume": "57" }, "uris": [ [ "http://www.mendeley.com/documents/?uid=077b60ac-6eb1-4b7b-966e-d66634d25e47" ] ] }, "mendeley": { "formattedCitation": "(6)", "plainTextFormattedCitation": "(6)", "previouslyFormattedCitation": "(6)" }, "properties": { "noteIndex": 0 }, "schema": "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" }}, and using conventional radiographs after seven weeks of orthodontic treatment {ADDIN CSL\_CITATION { "citationItems": [ { "id": "ITEM-1", "itemData": { "DOI": "10.1043/0003-3219(1995)065<0403:ROOIRR>2.0.CO;2", "ISBN": "0003-3219 (Print)\r0003-3219 (Linking)", "ISSN": "00033219", "PMID": "8702065", "abstract": "The aim of this investigation was to study the reparative potential of orthodontically induced root resorption. Sixty-four maxillary right and left first premolars in 32 patients (15 boys and 17 girls, mean age 13.7 years) were moved buccally with fixed orthodontic appliances and a continuous force of 50 cN (approximately 50 g), activated weekly for 6 weeks. The patients were divided into 4 groups of 8. Retention periods varied from 1 week to 8 weeks. Histological preparations showed that root resorption affected all the test teeth. The percentage of resorptive areas that had begun to repair ranged from 28% after 1 week of retention to 75% after 8

weeks. The healing cementum was almost exclusively of the cellular type. Partial repair, with the resorption cavity walls only partially covered with cementum, was the most frequent type of repair during the first 4 weeks of retention (17% to 31%). Functional repair, with the total surface of the resorption cavity walls covered with varying thicknesses of cementum, dominated after 5, 6, 7 and 8 weeks of retention (33% to 40%). There were no large differences in the healing potential in the cervical, middle, and apical thirds of the root. After 8 weeks, three out of four resorptive areas showed some degree of repair. Individual variations in healing potential were large.

"author": [ { "dropping-particle": "", "family": "Owman-Moll", "given": "P.", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Kuroi", "given": "J.", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Lundgren", "given": "D.", "non-dropping-particle": "", "parse-names": false, "suffix": "" } ], "container-title": "The Angle orthodontist", "id": "ITEM-1", "issue": "6", "issued": { "date-parts": [ [ "1995" ] ] }, "title": "Repair of orthodontically induced root resorption in adolescents.", "type": "article-journal", "volume": "65" }, "uris": [ "http://www.mendeley.com/documents/?uuiid=2a1975d2-51e1-47ce-92bb-cf8aed746f8e" ] ], "mendeley": { "formattedCitation": "(7)", "plainTextFormattedCitation": "(7)", "previouslyFormattedCitation": "(7)" }, "properties": { "noteIndex": 0 }, "schema": "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" }. Several studies have detected OIIRR of variable severity after 6 months of orthodontic treatment {ADDIN CSL\_CITATION { "citationItems": [ { "id": "ITEM-1", "itemData": { "DOI": "10.1016/j.ajodo.2003.12.030", "ISSN": "0889-5406 (Print)", "PMID": "16027626", "abstract": "INTRODUCTION: Individual predisposition might be a major reason for the observed variation in apical orthodontic root resorption. If so, resorption might be expressed during the initial stages of orthodontic therapy in patients at risk. METHODS: To explore this hypothesis, we evaluated standardized, digitized periapical radiographs made before treatment (T1) and at a mean period of 6.4 months (SD 0.9) after placement of maxillary incisor brackets (T2) in 290 patients (age range, 10.1 to 57.1 years at T1). Anamnestic and treatment parameters were recorded according to a protocol, and maxillary incisor irregularity was measured on T1 study models. RESULTS: The mean average root resorption for 4 incisors was 0.53 mm (SD 0.47), whereas the sample mean of the most severely resorbed tooth per patient was 1.18 mm (SD 0.86). A total of 4.1% of the patients had an average resorption of 1.5 mm or more, and 15.5% had at least 1 tooth with 2.0 mm or more resorption. The maximum amount of resorption was 4.4 mm. Multivariate linear regression showed that deviated root form and increased T1-to-T2 time period were risk factors for apical root resorption of the central incisors; normal root form and wide roots were preventive factors, with an explained variance of 14%. Similarly, long roots, narrow roots, and increased T1-to-T2 time period were risk factors for resorption of the lateral incisors, whereas normal root form was a preventive factor, with an explained variance of 24%. Parameters associated with use of rectangular wire, presence of incisor irregularity, and history of trauma were not identified as risk factors. Use of elastics was not included in the regression analyses. CONCLUSIONS: Root resorption can begin in the early leveling stages of orthodontic treatment. About 4.1% of patients studied had an average resorption of 1.5 mm or more of the 4 maxillary incisors, and about 15.5% had 1 or more maxillary incisors with resorption of 2.0 mm or more from 3 to 9 months after initiation of fixed appliance therapy. Although teeth with long, narrow, and deviated roots are at increased risk of resorption during this early stage, the explained variance of these risk factors is less than 25%." }, { "dropping-particle": "", "family": "Smale", "given": "Isolde", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Artun", "given": "Jon", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Behbehani", "given": "Faraj", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Doppel", "given": "Diane", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "van't Hof", "given": "Martin", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Kuijpers-Jagtman", "given": "Anne M", "non-dropping-particle": "", "parse-names": false, "suffix": "" } ], "container-title": "American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics", "id": "ITEM-1", "issue": "1", "issued": { "date-parts": [ [ "2005" ] ] }, "page": "57-67", "title": "Apical root resorption 6 months after initiation of fixed orthodontic appliance therapy." }

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Sensitivity increased significantly with cavity size. After 3 months apical root resorption was detected in only a few teeth. The number had increased significantly after 6 months. There was a higher degree of root resorption in teeth with blunt and pipette-shaped apices. In such teeth a 3-month radiographic control is recommended.", "author" : [ { "dropping-particle" : "", "family" : "Levander", "given" : "E", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Bajka", "given" : "R", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Malmgren", "given" : "O", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "European journal of orthodontics", "id" : "ITEM-2", "issue" : "1", "issued" : { "date-parts" : [ [ "1998" ] ] }, "page" : "57-63", "title" : "Early radiographic diagnosis of apical root resorption during orthodontic treatment: a study of maxillary incisors.", "type" : "article-journal", "volume" : "20" }, "uris" : [ "http://www.mendeley.com/documents/?uuid=1acbbf9a-0824-448c-8a46-22a6cf5aa444" ] } ], "mendeley" : { "formattedCitation" : "(8,9)", "plainTextFormattedCitation" : "(8,9)", "previouslyFormattedCitation" : "(8,9)", "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" }. Few studies have been conducted to investigate the influence of orthodontic bracket design, prescription and bracket slot size on the severity of OIIRR. Most clinical trials have reported that the influence of orthodontic bracket design on the severity of OIIRR is insignificant {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1016/j.ajodo.2014.12.026", "ISBN" : "4201400891", "ISSN" : "08895406", "PMID" : "25919107", "abstract" : "Introduction In this systematic review, we assessed the literature to determine which evidence level supports the association of orthodontic force system and root resorption. Methods PubMed, Cochrane, and Embase databases were searched with no restrictions on year, publication status, or language. Selection criteria included human studies conducted with fixed orthodontic appliances or aligners, with at least 10 patients and the force system well described. Results A total of 259 articles were retrieved in the initial search. After the review process, 21 full-text articles met the inclusion criteria. Sample sizes ranged from 10 to 73 patients. Most articles were classified as having high evidence levels and low risks of bias. Conclusions Although a meta-analysis was not performed, from the available literature, it seems that positive correlations exist between increased force levels and increased root resorption, as well as between increased treatment time and increased root resorption. Moreover, a pause in tooth movement seems to be beneficial in reducing root resorption because it allows the resorbed cementum to heal. The absence of a control group, selection criteria of patients, and adequate examinations before and after treatment are the most common methodology flaws.", "author" : [ { "dropping-particle" : "", "family" : "Roscoe", "given" : "Marina G.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Meira", "given" : "Josete B C", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Cattaneo", "given" : "Paolo M.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "American Journal of Orthodontics and Dentofacial Orthopedics", "id" : "ITEM-1", "issue" : "5", "issued" : { "date-parts" : [ [ "2015" ] ] }, "page" : "610-626", "title" : "Association of orthodontic force system and root resorption: A systematic review", "type" : "article-journal", "volume" : "147" }, "uris" : [ "http://www.mendeley.com/documents/?uuid=0e59cc2f-ac23-4c44-a3e2-a6ff6a23bb98" ] }, { "id" : "ITEM-2", "itemData" : { "ISBN" : "1434-5293 (Print)\r1434-5293 (Linking)", "PMID" : "9577105", "abstract" : "The purpose of this paper was to compare radiographically the prevalence and degree of apical root resorption after treatment with a fully programmed edgewise appliance (FPA) and a partly programmed edgewise appliance (PPA) in a randomized multipractice clinical



trial. Two groups of patients with Class II malocclusions were treated orthodontically. The type of treatment was randomly assigned by a computer program. During fixed appliance therapy, one group was treated according to the precepts of the straight wire concept (FPA; n = 32) while the other was treated with conventional full edgewise mechanics (PPA; n = 29). Treatment times were recorded. Radiographs of the maxillary incisors were made before and after active treatment with fixed appliances using the bisecting angle technique. To correct for different projecting angles the pairs of radiographs were digitally reconstructed. The prevalence and degree of root resorption were assessed. The mean treatment time was 1.8 years and 1.6 years for treatment with FPA and PPA, respectively. The mean amount of loss of tooth length was 8.2% for the patients treated with FPA and 7.5% for the patients treated with PPA. No statistically significant differences could be assessed between both groups at the end of active treatment. The mean prevalence of apical root resorption was 75% for the patients treated with FPA and 55% for the patients treated with PPA. Statistical evaluation showed no significant differences. We concluded that the prevalence and degree of root resorption is independent of the appliances as used in this study.

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or conventional brackets: a systematic review and meta-analysis.", "type": "article-journal", "volume": "16" }, "uris": [ "http://www.mendeley.com/documents/?uuiid=1fca2d88-4dd8-44ae-8d67-752a64ac4c2e" ] }, "mendeley": { "formattedCitation": "(12)", "plainTextFormattedCitation": "(12)", "previouslyFormattedCitation": "(12)", "properties": { "noteIndex": 0 }, "schema": "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" }. Reukers et al. {ADDIN CSL\_CITATION { "citationItems": [ { "id": "ITEM-1", "itemData": { "ISBN": "1434-5293 (Print)\r1434-5293 (Linking)", "PMID": "9577105", "abstract": "The purpose of this paper was to compare radiographically the prevalence and degree of apical root resorption after treatment with a fully programmed edgewise appliance (FPA) and a partly programmed edgewise appliance (PPA) in a randomized multipractice clinical trial. Two groups of patients with Class II malocclusions were treated orthodontically. The type of treatment was randomly assigned by a computer program. During fixed appliance therapy, one group was treated according to the precepts of the straight wire concept (FPA; n = 32) while the other was treated with conventional full edgewise mechanics (PPA; n = 29). Treatment times were recorded. Radiographs of the maxillary incisors were made before and after active treatment with fixed appliances using the bisecting angle technique. To correct for different projecting angles the pairs of radiographs were digitally reconstructed. The prevalence and degree of root resorption were assessed. The mean treatment time was 1.8 years and 1.6 years for treatment with FPA and PPA, respectively. The mean amount of loss of tooth length was 8.2% for the patients treated with FPA and 7.5% for the patients treated with PPA. No statistically significant differences could be assessed between both groups at the end of active treatment. The mean prevalence of apical root resorption was 75% for the patients treated with FPA and 55% for the patients treated with PPA. Statistical evaluation showed no significant differences. We concluded that the prevalence and degree of root resorption is independent of the appliances as used in this study.", "author": [ { "dropping-particle": "", "family": "Reukers", "given": "E A", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Sanderink", "given": "G C", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Kuijpers-Jagtman", "given": "A M", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "van't Hof", "given": "M A", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "J Orofoc Orthop", "given": "J", "non-dropping-particle": "", "parse-names": false, "suffix": "" } ], "container-title": "J Orofoc Orthop", "id": "ITEM-1", "issue": "2", "issued": { "date-parts": [ [ "1998" ] ] }, "page": "100-109", "title": "Radiographic evaluation of apical root resorption with 2 different types of edgewise appliances. Results of a randomized clinical trial", "type": "article-journal", "volume": "59" }, "uris": [ "http://www.mendeley.com/documents/?uuiid=c267b8cc-e1c2-460b-a46b-32e3b21635c0" ] }, "mendeley": { "formattedCitation": "(11)", "plainTextFormattedCitation": "(11)", "previouslyFormattedCitation": "(11)", "properties": { "noteIndex": 0 }, "schema": "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } } conducted a randomized clinical trial that investigated the difference in severity of OIIRR between the standard edgewise bracket system (0.018-inch slot) and pre-adjusted edgewise Roth prescription brackets (0.022-inch slot). The authors reported no statistically significant difference between the two bracket slot systems. However, the difference in bracket prescription between the two study groups was a potential confounding factor influencing the results.

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dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "Angle Orthodontist", "id" : "ITEM-1", "issue" : "2", "issued" : { "date-parts" : [ [ "2002" ] ] }, "page" : "180-184", "title" : "Orthodontically Induced Inflammatory Root Resorption. Part II: The Clinical Aspects", "type" : "article", "volume" : "72" }, "uris" : [ "http://www.mendeley.com/documents/?uuiid=89b4e744-87dd-4a10-92e2-6aa57ae7c6e3" ] } ], "mendeley" : { "formattedCitation" : "(13)", "plainTextFormattedCitation" : "(13)", "previouslyFormattedCitation" : "(13)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" }}. The orthodontic forces required for tooth movement are often associated with discomfort or pain {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1093/ejo/cj1081", "ISBN" : "0141-5387 (Print)\r0141-5387 (Linking)", "ISSN" : "01415387", "PMID" : "17488999", "abstract" : "Orthodontic pain, the most cited negative effect arising from orthodontic force application, is a major concern for parents, patients, and clinicians. Studies have reported this reaction to be a major deterrent to orthodontic treatment and an important reason for discontinuing treatment. Surprisingly this area, which requires attention in clinical practice as well as in research, is ignored as evidenced by the scarcity of publications on the topic in comparison with other areas of orthodontic research. This review attempts to organize the existing published literature regarding pain, which appears as part of orthodontic mechanotherapy and to address questions that might arise in a clinical setting from the viewpoint of clinicians and patients/parents. It also provides an overview of current management strategies employed for alleviating orthodontic pain.", "author" : [ { "dropping-particle" : "", "family" : "Krishnan", "given" : "Vinod", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "European journal of orthodontics", "id" : "ITEM-1", "issue" : "2", "issued" : { "date-parts" : [ [ "2007" ] ] }, "page" : "170-179", "title" : "Orthodontic pain: from causes to management--a review.", "type" : "article", "volume" : "29" }, "uris" : [ "http://www.mendeley.com/documents/?uuiid=1ae7ea0e-0ca8-4881-b09d-620fb4b9fdc3" ] } ], "mendeley" : { "formattedCitation" : "(14)", "plainTextFormattedCitation" : "(14)", "previouslyFormattedCitation" : "(14)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" }}. This is considered to be one of the biological side effects that can have a significant influence on patient perception of orthodontic treatment particularly in early stages during alignment {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1093/ejo/cj1081", "ISBN" : "0141-5387 (Print)\r0141-5387 (Linking)", "ISSN" : "01415387", "PMID" : "17488999", "abstract" : "Orthodontic pain, the most cited negative effect arising from orthodontic force application, is a major concern for parents, patients, and clinicians. Studies have reported this reaction to be a major deterrent to orthodontic treatment and an important reason for discontinuing treatment. Surprisingly this area, which requires attention in clinical practice as well as in research, is ignored as evidenced by the scarcity of publications on the topic in comparison with other areas of orthodontic research. This review attempts to organize the existing published literature regarding pain, which appears as part of orthodontic mechanotherapy and to address questions that might arise in a clinical setting from the viewpoint of clinicians and patients/parents. It also provides an overview of current management strategies employed for alleviating orthodontic pain.", "author" : [ { "dropping-particle" : "", "family" : "Krishnan", "given" : "Vinod", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "European journal of orthodontics", "id" : "ITEM-1", "issue" : "2", "issued" : { "date-parts" : [ [ "2007" ] ] }, "page" : "170-179", "title" : "Orthodontic pain: from causes to management--a review.", "type" : "article", "volume" : "29" }, "uris" : [ "http://www.mendeley.com/documents/?uuiid=1ae7ea0e-0ca8-4881-b09d-620fb4b9fdc3" ] } ], "mendeley" : { "formattedCitation" : "(14)", "plainTextFormattedCitation" : "(14)", "previouslyFormattedCitation" : "(14)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" }}. Orthodontic pain can range from mild to severe discomfort {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.2319/121308-632R.1", "ISBN" : "0003-3219 (Print)\r0003-3219 (Linking)", "ISSN" : "00033219", "PMID" : "19852612", "abstract" : "OBJECTIVE: To explore whether patients' pain experiences and orthodontists' assessments of their patients' pain levels are consistent and whether orthodontists are aware of their patients' use of pain medication. MATERIALS AND METHODS: Survey data were collected from 116 adolescent patients (44 male,

72 female; aged 10 to 19 years; mean age, 14.27 years) and from their orthodontic care providers.

**RESULTS:** While only 18.0% of these patients agreed that they had pain during their last orthodontic appointment, 58.5% indicated that they experienced pain for a few days after their appointment. On average, dentists underestimated the patients' pain during the last appointment (rated on a 5-point scale, with 1 indicating no pain: providers = 2.01 vs patients = 2.28;  $P = .042$ ), immediately after the last appointment (1.93 vs 2.34;  $P = .005$ ), and 1 day (1.77 vs 2.53;  $P < .001$ ) and 2 days (1.57 vs 2.19;  $P < .001$ ) after the previous appointment. Only 26.5% of the patients used pain medication immediately following and 1 day after the last appointment. Providers underestimated the amount of medication used.

**CONCLUSION:** Orthodontists underestimated the degree to which orthodontic treatment caused pain for their patients and their patients' use of pain medication.

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There is no evidence that archwire or bracket type choice can have an influence on pain perception during the orthodontic treatment {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1002/14651858.CD007859.pub3", "ISBN" : "1469-493X (Electronic)\r1361-6137 (Linking)", "ISSN" : "1469-493X", "PMID" : "23633347", "abstract" : "BACKGROUND: Initial arch wires are the first arch wires to be inserted into the fixed appliance at the beginning of orthodontic treatment and are used mainly for the alignment of teeth by correcting crowding and rotations. With a number of different types of orthodontic arch wires available for initial tooth alignment, it is important to understand which wire is most efficient, as well as which wires cause the least amount of root resorption and pain during the initial aligning stage of treatment. This is an update of the review 'Initial arch wires for alignment of crooked teeth with \u00f0xed orthodontic braces' first published in the Cochrane Database of Systematic Reviews 2010, Issue 4. OBJECTIVES: To assess the effects of initial arch wires for alignment of teeth with fixed orthodontic braces in relation to alignment speed, root resorption and pain intensity. SEARCH METHODS: We searched the following electronic databases: the Cochrane Oral Health Group's Trials Register (to 2 August 2012), CENTRAL (The Cochrane Library 2012, Issue 7), MEDLINE via OVID (1950 to 2 August 2012) and EMBASE via OVID (1980 to 2 August 2012). We also searched the reference lists of relevant articles. There was no restriction with regard to publication status or language of publication. We contacted all authors of included studies to identify additional studies. SELECTION CRITERIA: We included randomised controlled trials (RCTs) of initial arch wires to align teeth with fixed orthodontic braces. Only studies involving participants with upper and/or lower full arch fixed orthodontic appliances were included. DATA COLLECTION AND ANALYSIS: Two review authors were responsible for study selection, validity assessment and data extraction. All disagreements were resolved by discussion amongst the review team. Corresponding authors of included studies were contacted to obtain missing information. MAIN RESULTS: Nine RCTs with 571 participants were included in this review. All trials were at high risk of bias and a number of methodological limitations were identified. All trials had at least one potentially confounding factor (such as bracket type, slot size, ligation method, extraction of teeth) which is likely to have influenced the outcome and was not controlled in the trial. None of the trials reported the important adverse outcome of root resorption. Three groups of comparisons were made. (1) Multistrand stainless steel initial arch wires compared to superelastic nickel titanium (NiTi)\u0026", "author" : [ { "dropping-particle" : "", "family" : "Jian", "given" : "Fan", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Lai", "given" : "Wenli", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Furness", "given" : "Susan", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "McIntyre", "given" : "Grant T",

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Currently, there is insufficient evidence relating the influence of different bracket slot systems to the effectiveness of orthodontic treatment. The randomised clinical trial is the study design of choice to compare the two common bracket slot size systems (0.018-inch and 0.022-inch) in terms of severity of OIIRR and patient perception of pain during treatment.

### **Specific objectives or hypotheses**

This study is the third report of a randomized clinical trial that prospectively compared the effectiveness of orthodontic treatment with the two bracket slot sizes. Here, we present the secondary outcomes of the trial in terms of the biological side effects in the form of OIIRR as well as patient perception of pain during treatment. Moreover, this report investigates several factors that potentially influence the severity of OIIRR including a history of dental trauma and abnormal root morphology.

The null hypothesis was: there is no significant difference between the 0.018-inch or 0.022-inch slot bracket systems in terms of (1) severity of OIIRR (2) patient perception of pain during treatment. Parts 1 and 2 (17,18) report the results for the duration of treatment and quality of treatment, respectively.

## **METHODS**

### **Trial design and any changes after trial commencement**

This was a 2-arm parallel active group randomised clinical trial with a 1:1 allocation ratio. There were no changes to the method after trial commencement.

### **Participants, eligibility criteria, and setting**

In the UK, state-funded orthodontic treatment is provided through the NHS for patients scoring Index of Orthodontic Treatment Need (IOTN) Dental Health Component (DHC) 3 Aesthetic Component (AC) 6 and above (moderate to complex cases) by office-based Specialist Orthodontists working with a team of Orthodontic Therapists, and hospital/faculty Orthodontists trained to Consultant level who also provide competitive-entry graduate programs for Specialist and Consultant-level training. All patients referred for hospital Orthodontic care from January 2010 to September 2014 with good oral hygiene and a caries-free dentition were invited to participate in the study. The study was conducted in three sites however, one site was unable to recruit to the study and so was withdrawn, leaving two sites that contributed the participants for the study. The participants were selected according to the following criteria: aged 12 years and above with any type of malocclusion who were scheduled for dual arch fixed appliance orthodontic treatment. The exclusion criteria for the study were patients who had [1] undergone previous orthodontic treatment/functional appliances, [2] orofacial clefts, [3] severe hypodontia, [4] special needs, and [5] required orthodontic-orthognathic surgery treatment. They did not take part and were not included in any analysis. Patients who met the inclusion criteria for the study received the patient information sheet and where relevant, the parent

information sheet was also issued. The consent process was completed after obtaining patient/parent assent to participate in the study.

The work was carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki). Ethical approval was obtained from the NHS Tayside Committee on Medical Research Ethics (East of Scotland Ethics Service) in October 2009 (REC Reference: 09/S1401/56) and Research and Development (R&D) approval was obtained from the NHS Tayside Research and Development in November 2009.

### Interventions

The treatment involved initially polishing the teeth with pumice and water, and using a self-etching primer (Transbond™ Plus Self Etching Primer, 3M-Unitek, Monrovia, USA) to prepare the teeth for bracket placement. Adhesive pre-coated (APC) brackets/buccal tubes (APC™ II Victory Series™ Twin MBT™, 3M-Unitek, Monrovia, USA) were bonded according to the allocation group, i.e. either 0.018-inch or 0.022-inch slot MBT prescription. Bands were used on molars where a transpalatal arch or quadhelix was required.

A predetermined archwire sequence for each bracket slot system was followed (<http://multimedia.3m.com/mws/media/7365760/wire-selection-for-optimal-biomechanic-efficiency-dr-d-segner.pdf>). The archwire sequence for the 0.018-inch bracket slot system was: 0.016-inch super elastic nickel-titanium, 0.016 × 0.022-inch super elastic nickel-titanium, and 0.016 × 0.022-inch stainless steel archwires. For the 0.022-inch bracket slot system, the sequence was: 0.016-inch super elastic nickel-titanium, 0.019 × 0.025-inch super elastic nickel-titanium, and 0.019 × 0.025-inch stainless steel archwires. Appliances were routinely adjusted at an interval of 6-8 weeks. All appliances were ligated using conventional elastomeric ligation unless stainless steel ligatures were required for severely rotated or ectopic teeth. All the participants received a standard treatment regime according to the treatment protocol throughout the trial. Extraction spaces were closed using sliding mechanics with closed coil springs or elastomeric chains. Minor deviations from the standard protocol were accepted for certain clinical circumstances (e.g. use of “piggy back” wires), but no special techniques or additional appointments were required for the study. Appliances were debonded and retainers provided when a Class I incisor and canine relationship, a well interdigitating buccal segment relationship and all other treatment goals had been established. Prematurely terminated cases were due to poor patient compliance.

Digital orthopantomographs were taken for all study participants before the start of treatment as part of the routine orthodontic assessment. Periapical radiographs with a long cone paralleling technique for the maxillary central incisors were taken at the start of treatment and after nine months from the start of treatment. In addition, digital lateral cephalometric radiographs were taken at the start and near end of treatment [UK orthodontic radiography guidelines by Isaacson et al.]{ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "author" : [ { "dropping-particle" : "", "family" : "Isaacson KG, Thom AR, Horner K", "given" : "Whaites E.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "British Orthodontic Society", "id" : "ITEM-1", "issued" : { "date-parts" : [ [ "2008" ] ] }, "title" : "Orthodontic radiographs: Guidelines", "type" : "book" }, "uris" : [ "http://www.mendeley.com/documents/?uuid=3d733e6c-8b3b-42e9-aa65-86095f1edf51" ] } ], "mendeley" : { "formattedCitation" : "(17)", "plainTextFormattedCitation" : "(17)", "previouslyFormattedCitation" : "(17)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" }}, updated by Isaacson et al.]{ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1016/j.ajodo.2015.10.014", "ISSN" : "0889-5406", "abstract" : "Tel: +44 (0)20 7353 8680 Fax: +44 (0)20 7353 8682 www.bos.org.uk British Library Cataloguing Data A catalogue record for this book is available from the British Library ISBN 1 899297 09 X X 2 IN 1994 The British Society for the Study of Orthodontics (BSSO) asked the Standards Committee to develop guidelines for the use of radiographs in orthodontics, which formed the basis for the first edition. This was one of the first published sets of guidelines for dentistry. The initial work done by the members of the Committee has been the basis for further editions. In 2000 the Ionising Radiation

(Medical Exposure) Regulations (IRMER) 1 were published and these were incorporated into the subsequent editions. The need for a fourth edition is due to the increasing availability of Cone Beam Computed Tomography (CBCT) which usually enables dento-maxillofacial imaging with a lower exposure than conventional CT. Such machines are now readily available and are being promoted as 3D imaging techniques for the teeth and jaws. Some orthodontists are using them as part of orthodontic treatment planning and, although the exposure is usually less than a conventional CT, it can be at least 20 times greater than normal dental radiography. 2 CBCT imaging has a useful place in selected cases and European evidence-based guidelines for their use have been formulated by the SEDENTEXCT project. 3 In this edition a new section on CBCT has been added which takes these European guidelines into account and discusses their place in orthodontic treatment. The majority of changes in this fourth edition are due to the expertise of the dental and maxillofacial radiologists", "author" : [ { "dropping-particle" : "", "family" : "Isaacson", "given" : "K G", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Thom", "given" : "A R", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Horner", "given" : "K", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Whaites", "given" : "E", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "British Orthodontic Society", "id" : "ITEM-1", "issue" : "0", "issued" : { "date-parts" : [ [ "2015" ] ] }, "number-of-pages" : "1-28", "title" : "Guidelines for the use of radiographs in clinical orthodontics", "type" : "book" }, "uris" : [ "http://www.mendeley.com/documents/?uid=a667ddf-dbe02-4de1-aae4-b7ea187e91c4" ] } ], "mendeley" : { "formattedCitation" : "(18)", "plainTextFormattedCitation" : "(18)", "previouslyFormattedCitation" : "(18)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } } ] }

#### Standardisation of periapical radiographs

All periapical radiographic request forms for the study were sent to the Dental and Maxillofacial Radiology Department and colour coded for trial identification to ensure standardisation of the long cone periapical radiograph technique. Radiographic films were placed using a film holder with a forty-cm film-source distance. The radiographs were generated at 60 kv and 7 mA Dc with an 0.20 s exposure. The periapical radiographs taken in this study were of two types depending on availability in the study centers:

- Digitised conventional film: conventional film radiographs [F speed film (www.carestream.com)] were digitized using a flatbed scanner [Epson perfection v750PRO (www.epson.com)] as 16 bit grayscale images at 300 dpi;
- Digital radiographs: taken using the phosphor plate (PPS) radiograph [Dürr Dental (www.duerr.co.uk)].

The radiographic images were coded (for blinding) and saved in JPG form and imported for measurements into Image J Link 1.4 software (<http://rebweb.nih.gov/ij/index.html>). An auxiliary validity in-vitro experimental study was undertaken by the current research team to confirm the validity and agreement of measurements from digitized periapical radiographs produced by scanning conventional films in measuring root shortening when compared to the phosphor plate digital imaging {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.4317/jced.50872", "ISBN" : "1989-5488 (Electronic)\n1989-5488 (Linking)", "ISSN" : "19895488", "PMID" : "24455036", "abstract" : "OBJECTIVES: The aim of this study was to compare the accuracy and agreement of scanned film and digital periapical radiographs for the measurement of apical root shortening.\n\nSTUDY DESIGN: Twenty-four film and digital [phosphor plate sensor (PPS)] periapical radiographs were taken using the long-cone paralleling technique for six extracted teeth before and after 1mm of apical root trimming. All teeth were mounted using a typodont and the radiographs were recorded using a film holder and polysiloxane occlusal index for each tooth to ensure standardization during the different radiographic exposures. The film radiographs were scanned and the tooth length measurements for the scanned film and digital (PPS) images were calculated using Image-J-Link 1.4 software (<http://rebweb.nih.gov/ij/index.html>) for the two groups. The accuracy and agreement among the tooth length measurements from each group and the true tooth length measurements were calculated

using intra-class correlation (ICC) tests and Bland and Altman plots. RESULTS: A high level of agreement was found between the true tooth length measurements and the scanned film measurements (ICC=0.979, limit of agreement 0.579 to -0.565) and the digital (PPS) radiograph measurements (ICC= 0.979, limit of agreement 0.596 to -0.763). Moreover, a high level of agreement was found between the scanned film and digital (PPS) radiographs for the measurement of tooth length ICC=0.991, limit of agreement 0.411-0.231. CONCLUSION: Film and digital (PPS) periapical radiographs are accurate methods for measuring apical root shortening with a high level of agreement. Key words:Root shortening, measurement, periapical radiographs, film, digital.

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#### Outcomes and any changes after trial commencement

This article presents the secondary outcome measures of the randomised clinical trial which compared the severity of OIIRR and patient pain/discomfort during orthodontic treatment with 0.018-inch or 0.022-inch bracket slot systems. All the records were anonymised and the measurements were undertaken by the investigators (G.M and A.E) who were blinded to the study group allocation during assessment and therefore identification of the group allocation was not possible. There were no outcome changes after trial commencement except for the dropout of one of the centres, however, since this was at the beginning of recruitment, it did not impact on the study results. The other two centres were able to recruit a sufficient number of patients..

#### Orthodontically induced inflammatory root resorption

OIIRR was evaluated in this study by assessing the severity of apical root resorption affecting the maxillary central incisors using standardised long-cone periapical radiographs. Pre-treatment radiographs were taken for all trial participants before the start of treatment (PA0) and 9 months after the start of treatment (PA1).

Investigators were blinded for the study groups during radiographic analysis for assessing apical OIIRR as all the radiographs were coded in advance of being assessed. All the radiographs were rescored by the same investigators after an interval of 3 weeks to evaluate intra- and inter-investigator reliability.

#### Method of assessing apical OIIRR from periapical radiograph

The severity of OIIRR was assessed using a scoring index that was adapted from Malmgren et al. ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1016/0002-9416(82)90317-7", "ISBN" : "0002-9416 (Print)\r0002-9416 (Linking)", "ISSN" : "00029416", "PMID" : "6961819", "abstract" : "This study concerns the frequency and degree of root resorption in traumatized incisors that have been treated orthodontically. The subjects were twenty-seven patients (fifteen boys and twelve girls) with fifty-five traumatized incisors; fifty-five consecutive patients without traumatized teeth served as controls. All the control patients were treated with extraction of four first premolars and a fixed appliance (thirty-three with an edgewise and twenty-two with a Begg appliance). Signs of root resorption were registered with index scores from 0 to 4 (Fig. 1). The degree of root resorption in traumatized teeth was compared to that in the uninjured



control teeth in the same patient and in the patients without trauma. Neither the intraindividual nor the interindividual comparisons support the hypothesis that traumatized teeth have a greater tendency toward root resorption than uninjured teeth. Root resorption (scores 2 to 4) was found in 51 percent of the traumatized incisors, in 43 percent of the incisors treated with edgewise appliances, and in 48 percent of those treated with Begg appliances. Traumatized teeth with signs of root resorption prior to orthodontic treatment may be more prone to root resorption during treatment. \u00a9 1982.", "author" : [ { "dropping-particle" : "", "family" : "Malmgren", "given" : "Olle", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Goldson", "given" : "Lars", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Hill", "given" : "Carsten", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Orwin", "given" : "Anders", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Petri", "given" : "Lars", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Lundberg", "given" : "Margareta", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "American Journal of Orthodontics", "id" : "ITEM-1", "issue" : "6", "issued" : { "date-parts" : [ [ "1982" ] ] }, "page" : "487-491", "title" : "Root resorption after orthodontic treatment of traumatized teeth", "type" : "article-journal", "volume" : "82" }, "uris" : [ "http://www.mendeley.com/documents/?uid=f98421e0-afe0-4a38-88b4-4b26d1faad42" ] }, "mendeley" : { "formattedCitation" : "(20)", "plainTextFormattedCitation" : "(20)", "previouslyFormattedCitation" : "(19)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" }

- Grade 0: absence of apical root resorption
- Grade 1: irregular apical root contour
- Grade 2: minor apical root resorption, small area of root loss amounting to less than 2mm
- Grade 3: severe apical root resorption from 2mm to one third of the original root length
- Grade 4: extreme apical root resorption exceeding one third of the original root length.

The OIIRR scoring for the right and left maxillary central incisors for each participant were combined by taking the highest score (Figure 1) to represent a single dependent variable “upper central incisors OIIRR score”.

#### Method of assessing root morphology

Root morphology (Figure 1) was assessed for abnormality in the pre-treatment periapical radiograph using the index below which was adopted from Levander et al. {ADDIN CSL\_CITATION { "citationItems" : [ [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1093/ejo/20.1.57", "ISBN" : "0141-5387 (Print)\r0141-5387 (Linking)", "ISSN" : "0141-5387", "PMID" : "9558765", "abstract" : "The purpose of this study was to evaluate the sensitivity of digital radiographs for detection of (i) simulated root resorption cavities in an experimental model and (ii) orthodontically-induced apical root resorption in vivo. The severity of root resorption after 3 and 6 months treatment was studied in relation to root form. The experimental study cavities, drilled in mandibular roots in a dry skull, were recorded in conventional and digital radiographs. In vivo root resorption was evaluated on digital radiographs of 92 maxillary incisors after 3 and 6 months treatment with fixed appliances. The results showed a similar sensitivity for the two methods. Sensitivity increased significantly with cavity size. After 3 months apical root resorption was detected in only a few teeth. The number had increased significantly after 6 months. There was a higher degree of root resorption in teeth with blunt and pipette-shaped apices. In such teeth a 3-month radiographic control is recommended.", "author" : [ { "dropping-particle" : "", "family" : "Levander", "given" : "E", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Bajka", "given" : "R", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Malmgren", "given" : "O", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "European journal of orthodontics", "id" : "ITEM-1", "issue" : "1", "issued" : { "date-parts" : [ [ "1998" ] ] }, "page" : "57-63", "title" : "Early radiographic diagnosis of apical root resorption during orthodontic treatment: a study of maxillary incisors.", "type" : "article-journal", "volume" : "20" }, "uris" : [ "http://www.mendeley.com/documents/?uid=1acbbf9a-0824-448c-8a46-22a6cf5aa444" ] } ], "mendeley" : { "formattedCitation" : "(9)", "plainTextFormattedCitation" : "(9)",

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- Score 0: Normal root morphology
- Score 1: Short root
- Score 2: Blunt root
- Score 3: Root with apical bend
- Score 4: Root with apical pipette shape
```

#### *History of trauma*

History of dental trauma affecting the maxillary incisors was determined as a part of the initial orthodontic diagnostic assessment in the form of a yes or no question.

#### *Pain /discomfort*

A validated patient perception questionnaire was completed by the study participants at 6 months from the start of treatment {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1093/ejo/cjw076", "ISSN" : "0141-5387", "PMID" : "27864320", "abstract" : "BACKGROUND/OBJECTIVE To assess the validity and reliability of a series of three questionnaires for the quantification of patient perception of fixed appliance orthodontic treatment. SUBJECTS AND METHODS The study was carried out at the University of Dundee with content and face validity being assessed using proformas. Initially ten experts (Orthodontic Specialists) assessed content validity with 11 professionals (seven Orthodontic Specialists and four Postgraduates) and 20 patients assessing face validity. Content validity was determined according to the values of item-level content validity index (I-CVI) and scale-level CVI (S-CVI/Ave), while specially designed feedback forms were used for face validation. Internal consistency determined the reliability of the questionnaires according to the value of Cronbach alpha correlation coefficient test. The three questionnaires were then modified according to the recommendations of professionals and patients with seven experts reassessing content validity and ten newly selected patients assessing face validity. RESULTS The first round of content validity revealed that around half of the items in the questionnaires were not valid. Therefore, the questionnaires were not valid as a whole (S-CVI/Ave = 0.60). After modifying the questionnaires and removing the non-valid items, the new versions of the Pre-treatment, Orthodontic Experience, and Post-treatment Questionnaires showed high levels of face validity, content validity (S-CVI/Ave: 0.99, 0.97, and 0.99, respectively) and good levels of internal consistency ( $\alpha = 0.86, 0.78, \text{ and } 0.88$ , respectively). LIMITATION The patient sample was collected from a single university clinic and from one city within the UK and this could affect the generalizability of the results. CONCLUSION Three content valid and reliable questionnaires have been developed and validated for the evaluation of patient perception of fixed appliance orthodontic treatment. IMPLICATIONS Unlike other tools that assess oral health-related quality of life, this series of three questionnaires assess the perception of fixed appliance orthodontic treatment before, during and after treatment." }, { "dropping-particle" : "", "family" : "Yassir", "given" : "Yassir A.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "McIntyre", "given" : "Grant T.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Bearn", "given" : "David R.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "The European Journal of Orthodontics", "id" : "ITEM-1", "issued" : { "date-parts" : [ [ "2016" ] ] }, "page" : "cjw076", "title" : "Three questionnaires to assess the perception of fixed orthodontic therapy before, during and after treatment: validity and reliability", "type" : "article-journal" }, "uris" : [ "http://www.mendeley.com/documents/?uuid=cbd5e12b-578b-4fe5-9c08-1c2ea5702e99" ] } ], "mendeley" : { "formattedCitation" : "(21)", "plainTextFormattedCitation" : "(21)", "previouslyFormattedCitation" : "(20)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" }}. One of the domains of this questionnaire focused on assessing patient discomfort and soreness of both the teeth and the mouth during fixed appliance treatment.

#### **Sample size calculation**

Patients were recruited in this clinical trial according to the sample size calculation for the primary outcome which is the full duration of orthodontic treatment. A total of 197 participants were recruited in the current study based on detecting a difference of three months with a SD of 5.38 which was derived from the meta-analysis by Tsichlaki et al. (2016) {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1016/j.ajodo.2015.09.020", "ISSN" : "08895406", "PMID" : "26926017", "abstract" : "Introduction: There is little agreement on the expected duration of a course of orthodontic treatment; however, a consensus appears to have emerged that fixed appliance treatment is overly lengthy. This has spawned numerous novel approaches directed at reducing the duration of treatment, occasionally with an acceptance that occlusal outcomes may be compromised. The aim of this study was to determine the mean duration and the number of visits required for comprehensive orthodontic treatment involving fixed appliances. Methods: Multiple electronic databases were searched with no language restrictions, authors were contacted as required, and reference lists of potentially relevant studies were screened. Randomized controlled trials and nonrandomized prospective studies concerning fixed appliance treatment with treatment duration as an outcome measure were included. Data extraction and quality assessment were performed independently and in duplicate. Results: Twenty-five studies were included after screening: 20 randomized controlled trials and 5 controlled clinical trials. Twenty-two studies were eligible for meta-analysis after quality assessment. The mean treatment duration derived from the 22 included studies involving 1089 participants was 19.9 months (95% confidence interval, 19.58, 20.22 months). Sensitivity analyses were carried out including 3 additional studies, resulting in average duration of treatment of 20.02 months (95% confidence interval, 19.71, 20.32 months) based on data from 1211 participants. The mean number of required visits derived from 5 studies was 17.81 (95% confidence interval, 15.47, 20.15 visits). Conclusions: Based on prospective studies carried out in university settings, comprehensive orthodontic treatment on average requires less than 2 years to complete.", "author" : [ { "dropping-particle" : "", "family" : "Tsichlaki", "given" : "Alike", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Chin", "given" : "Siew Yee", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Pandis", "given" : "Nikolaos", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Fleming", "given" : "Padhraig S.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "American Journal of Orthodontics and Dentofacial Orthopedics", "id" : "ITEM-1", "issue" : "3", "issued" : { "date-parts" : [ [ "2016" ] ] }, "page" : "308-318", "title" : "How long does treatment with fixed orthodontic appliances last? A systematic review", "type" : "article", "volume" : "149" }, "uris" : [ "http://www.mendeley.com/documents/?uuid=1d0d11be-36ef-466b-903b-30c6ba30065f" ] } ], "mendeley" : { "formattedCitation" : "(22)", "plainTextFormattedCitation" : "(22)", "previouslyFormattedCitation" : "(21)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" }}. Moreover, a sample size calculation was also carried out for the severity of OIIRR as a representative of the secondary outcomes. A sample size of 16 participants in each group would have more than 80% power to detect a difference of 0.5mm (equivalent to score 1) with a 0.05 significant difference level.

### Interim analyses and stopping guidelines

This was determined if severe OIIRR was detected nine months from the start of treatment using periapical radiographs in the majority of patients in one group. This would mandate that the trial monitoring committee should be convened to consider whether the study would be terminated. This evaluation was undertaken by an independent clinician in order to preserve masking regarding the study groups.

### Randomization

Block randomisation was used to form the allocation list for the two comparison groups. A computer random number generator was implemented to select random permuted blocks with a block size of ten and an equal allocation ratio ({ [HYPERLINK "http://www.graphpad.com/quickcalcs/randomn2.cfm"](http://www.graphpad.com/quickcalcs/randomn2.cfm) }). Then, the final Allocation Table for

the participants in the study (which contained the study number and allocation group) was kept in a sealed envelope away from the clinical environment.

Allocation concealment was achieved with sequentially numbered, identical, opaque, and sealed envelopes which were prepared before the trial and contained the treatment allocation card. These were kept in a box and as the clinician obtained the informed consent, an independent dental nurse was responsible for identifying the next allocation envelope in the sequence to implement the randomisation process.

### **Blinding**

Due to the nature of this orthodontic trial, blinding to treatment allocation was only possible for the investigator and data analyst but was not possible for the clinicians and patients. The data were anonymised using 1 and 2 codes for the appliance types during the analysis. Thus, the data analyst could not identify allocation group during data analysis.

As soon as the allocation envelope was opened in preparation for appliance placement, both clinician and participant knew the type of appliance used. This allowed the clinicians to follow the recommended standard sequence of archwires for each appliance. Although patients were aware of the allocation group, they did not have previous experience with orthodontic treatment and could not recognise the difference between appliances.

### **Statistical analysis**

The data were analysed using the Statistical Package for Social Sciences for Windows, version 22.0 (SPSS Inc., Chicago, Illinois, USA). The following statistical analyses were used:

*Descriptive statistics:* These included: number, mean, standard deviation, frequency, and percentages.

*Reliability statistics:* The Kappa test was used to test Inter-examiner and intra-examiner reliability of periapical radiographs OIIRR scoring.

*Inferential statistics:* A "per-protocol" analysis was used. The two appliance groups were compared using: t-test test for continuous data. Chi-square, Friedman test, Kruskal-Wallis test and Wilcoxon signed-rank test were used for categorical data. The significance level was set as  $P < 0.05$ . Spearman's correlation coefficient test was used to assess the correlation between severity of OIIRR and several variables.

## **RESULTS**

### **Participant flow**

One hundred and ninety-seven patients were enrolled in the study. Ten patients did not attend for appliance placement or declined to participate. Therefore, 187 patients were randomised to either the 0.018'' or 0.022'' group in a 1:1 ratio. The 34 (Figure 2) who were lost to follow-up or who either experienced a protocol deviation or where there was very poor compliance were excluded from the study. Therefore 153 patients were included in the analysis (overall mean age:  $19.1 \pm 8.5$  years). Patient recruitment started in January 2010 and ended in September 2014 and the trial was completed as planned.

### **Baseline data**

Baseline characteristics including; age at bonding, gender, type of malocclusion, pre-treatment PAR score, and presence of extracted/missing and impacted teeth were found to be similar in both treatment arms ( $P > 0.05$ ) (Table 1). In addition, the baseline characteristics for the study dropout participants show almost similar distribution of age, gender and Pre-treatment PAR when compared to the analysed study sample in (Table 1).

### **Numbers analysed for each outcome, estimation and precision, subgroup analyses**

During the recruitment stage 216 patients were invited to participate in the study however, 19 patients declined and 197 participants were enrolled in the study with another 10 patient excluded

before the randomisation process (Figure 2). The total number of analyzed participants in the current trial for the OIIRR outcome was a total of 149 participants (74 for the 0.018-inch group and 75 for the 0.022-inch group) while for the patient perception of pain during treatment was 153 (77 for the 0.018-inch group and 76 for the 0.022-inch group). “Per-protocol” analysis was carried out utilising the data imputation wizard in SPSS for the OIIRR and patient perception to pain between the study groups. It was decided to use a “per-protocol” analysis as the excluded patients were either not eligible to fulfil the protocol, failed to comply with treatment or moved to another hospital or practice. However, to ensure that the drop-outs from the study did not significantly influence the study results an intention-to-treat analysis was also carried out which showed agreement with the “pre-protocol analysis”.

### **Reliability measurements**

Inter-examiner agreement for the OIIRR radiographic scoring was determined using the Kappa statistic. This showed substantial agreement (0.749) between the two investigators. The same test was also used for intra-examiner {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.4317/jced.50872", "ISBN" : "1989-5488 (Electronic)\n1989-5488 (Linking)", "ISSN" : "19895488", "PMID" : "24455036", "abstract" : "OBJECTIVES: The aim of this study was to compare the accuracy and agreement of scanned film and digital periapical radiographs for the measurement of apical root shortening.\n\nSTUDY DESIGN: Twenty-four film and digital [phosphor plate sensor (PPS)] periapical radiographs were taken using the long-cone paralleling technique for six extracted teeth before and after 1mm of apical root trimming. All teeth were mounted using a typodont and the radiographs were recorded using a film holder and polysiloxane occlusal index for each tooth to ensure standardization during the different radiographic exposures. The film radiographs were scanned and the tooth length measurements for the scanned film and digital (PPS) images were calculated using Image-J-Link 1.4 software (<http://rebweb.nih.gov/ij/index.html>) for the two groups. The accuracy and agreement among the tooth length measurements from each group and the true tooth length measurements were calculated using intra-class correlation (ICC) tests and Bland and Altman plots.\n\nRESULTS: A high level of agreement was found between the true tooth length measurements and the scanned film measurements (ICC=0.979, limit of agreement 0.579 to -0.565) and the digital (PPS) radiograph measurements (ICC= 0.979, limit of agreement 0.596 to -0.763). Moreover, a high level of agreement was found between the scanned film and digital (PPS) radiographs for the measurement of tooth length ICC=0.991, limit of agreement 0.411-0.231.\n\nCONCLUSION: Film and digital (PPS) periapical radiographs are accurate methods for measuring apical root shortening with a high level of agreement. Key words:Root shortening, measurement, periapical radiographs, film, digital.", "author" : [ { "dropping-particle" : "", "family" : "El-Angbawi", "given" : "Ahmed M F", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "McIntyre", "given" : "Grant T.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Bearn", "given" : "David R.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Thomson", "given" : "Donald J.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "Journal of Clinical and Experimental Dentistry", "id" : "ITEM-1", "issue" : "5", "issued" : { "date-parts" : [ [ "2012" ] ] }, "title" : "Film and digital periapical radiographs for the measurement of apical root shortening", "type" : "article-journal", "volume" : "4" }, "uris" : [ "http://www.mendeley.com/documents/?uid=6d5d57d9-3267-4c03-a743-7257c6d94a25" ] } ], "mendeley" : { "formattedCitation" : "(19)", "plainTextFormattedCitation" : "(19)", "previouslyFormattedCitation" : "(22)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } } reliability which indicated high agreement (0.938) between the two episodes.

### **Outcome measurements**

#### **OIIRR**

Data for OIIRR at start of treatment PA0 and 9 months in treatment PA1 for both study groups and the total study sample are shown in Figure 3 and Table 2. The Friedman test for repeated

ordinal variables was used to compare OIIRR score between T0 and T1 for the total sample and the two study groups. There was a statistically significant increase in the severity of OIIRR in T1 compared with T0 in the total sample and in the two study groups ( $P=0.000$ ). A Kruskal-Wallis test was used to compare the severity of OIIRR between 0.018 and 0.022 study groups at T0 and T1 (Table 3). No statistically significant difference was found between the two groups at neither T0 nor T1 ( $P=0.847$  and  $P=0.115$  respectively).

No statistically significant correlation was found between either OIIRR and a history of trauma, or abnormal root morphology of the maxillary central incisors  $R=0.042$ ,  $P=0.313$  and  $R=0.10$ ,  $P=0.086$  respectively (Table 4). No correlation was found between the duration of rectangular NiTi archwires use during the alignment stage and the severity of OIIRR ( $R=-0.43$ ,  $P=0.61$ ).

#### *Patient perception of pain*

Data from the patient questionnaire completed by participants at 6 months from the start of treatment showed that 10.6% of the participants reported “a lot of sore teeth” and 11.2% reported “no sore teeth” while the majority of the sample 78.2% reported “little sore teeth”. There was no statistically significant difference in the patient perception of pain between the two study groups ( $P=0.08$ ).

The correlation between the severity of pain and discomfort during fixed orthodontic treatment and severity of OIIRR was assessed for the total study sample using Spearman’s test (Table 4 and Figure 4). No statistically significant correlation was found between severity of OIIRR and severity of pain and discomfort during treatment ( $R=0.045$ ,  $P=0.617$ ).

#### **Harms**

No adverse reactions were reported during treatment.

#### **DISCUSSION**

This report presents the secondary outcomes of the trial comparing the 0.018-inch and 0.022-inch bracket slot systems in the form of OIIRR and patient perception of pain during treatment. No statistically significant difference was found between the two study groups for either of the variables that were investigated.

Comparison of the descriptive baseline variables indicated that there were no statistically significant differences between the two study groups. This ensured that the randomization process for the recruited sample was effective in producing study groups with almost similar pre-treatment characteristics. This reduced the influence of confounding factors when comparing between the two study groups and indicated that the results are valid and unlikely to be caused by any factor other than the intervention being investigated.

The severity of malocclusion for the sample recruited was evaluated in this study using several methods that included PAR score, severity of crowding and amount of irregularity in the upper and lower arches. The mean PAR score for both study groups was (31.2 and 31.6) which was higher than that reported by several previous studies with PAR scores between 24 – 29 {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1093/ejo/20.2.159", "ISBN" : "0141-5387 (Print)\r0141-5387 (Linking)", "ISSN" : "01415387", "PMID" : "9633169", "abstract" : "There is some concern that patients treated by postgraduate students during their specialty training may be disadvantaged in the quality of treatment result and subject to longer treatment times if they are treated by more than one operator. This study analysed the pre- and post-treatment study models of orthodontic patients from a district general hospital department, deboned by one junior member of junior staff in the calendar years 1991 and 1992. All

patients were treated using the same pre-adjusted edgewise appliance in both arches. Two groups of patients were identified: patients whose treatment was started and finished by the same operator (registrar A), and those whose treatment was begun by another operator (registrar B), but finished by registrar A. A random sample of 30 patients from each group was selected and the study models at the start and end of treatment were scored using the PAR (Peer Assessment Rating) Index. No significant differences were found between the average PAR scores for each group at the beginning of treatment, or between groups A and B at the end of treatment; the average treatment time for the patients treated by one operator was 17.67 months (SD 4.15 months), while the average treatment time for the patients treated by more than one operator was 26.1 months (SD 6.78 months). Statistically, this difference was highly significant ( $P < 0.001$ ). A highly linear relationship ( $R^2 = 0.92$ ) was found between the percentage PAR score reduction and the initial PAR score. The findings and their implications are discussed.

"author": [ { "dropping-particle": "", "family": "McGuinness", "given": "Niall J.", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "McDonald", "given": "James P.", "non-dropping-particle": "", "parse-names": false, "suffix": "" } ], "container-title": "European Journal of Orthodontics", "id": "ITEM-1", "issue": "2", "issued": { "date-parts": [ [ "1998" ] ] }, "page": "159-167", "title": "The influence of operator changes on orthodontic treatment times and results in a postgraduate teaching environment", "type": "article-journal", "volume": "20", "uris": [ "http://www.mendeley.com/documents/?uuiid=8656c665-f63b-47d5-93c0-cc679af73972" ] }, { "id": "ITEM-2", "itemData": { "ISBN": "0022-0337", "ISSN": "0022-0337", "abstract": "An accredited graduate orthodontic program provides advanced specialty education to meet standards of care mandated by the ADA, including both didactic and clinical components with defined outcome measures. To quantify these measures, the quality of care provided by graduate orthodontic students was compared to that of orthodontists in private practice. The quality of care was studied in two different delivery settings in the Columbus, Ohio, area-private practice orthodontists (PPO) and the OSU graduate orthodontic clinic (GOC). The Peer Assessment Rating (PAR) Occlusal Index was used as a measure of malocclusion severity and post-treatment occlusal outcome. Quality of care was measured using post-treatment PAR, percent PAR reduction, and treatment duration. At baseline, no differences were seen in the gender and pre-PAR scores of patients treated by the PPO and GOC, but statistically significant differences were seen in patients' pre-treatment age, race, and starting dentition. When the post-treatment occlusal results were compared, no statistically significant differences were seen in post-PAR scores and percent PAR reduction between the PPO and GOC. A statistically significant difference was seen in treatment duration ( $p = 0.002$ ), which was longer in the PPO even after controlling for confounding factors such as pre-treatment age, gender, race, starting dentition, and treatment stages. Our conclusion is that there was no statistically significant difference in the occlusal outcome between the PPO and GOC, but there was a significant difference in the treatment duration.", "author": [ { "dropping-particle": "", "family": "A.K.", "given": "Mascarenhas", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "K.", "given": "Vig", "non-dropping-particle": "", "parse-names": false, "suffix": "" } ], "container-title": "Journal of dental education", "id": "ITEM-2", "issue": "1", "issued": { "date-parts": [ [ "2002" ] ] }, "page": "94-99", "title": "Comparison of orthodontic treatment outcomes in educational and private practice settings", "type": "article", "volume": "66", "uris": [ "http://www.mendeley.com/documents/?uuiid=2892aa39-4e7c-4d79-862f-439fe56d5d7d" ] }, "mendeley": { "formattedCitation": "(23,24)", "plainTextFormattedCitation": "(23,24)", "previouslyFormattedCitation": "(23,24)" }, "properties": { "noteIndex": 0 }, "schema": "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" }. This may be explained by the referral policy within NHS for mainly complex cases to be accepted for treatment in consultant-led clinics.

The total number of participants analyzed in the current trial for OIIRR outcome were 149 participants (20% drop-out), while data were available for 153 for the perception of pain during treatment (18% drop-out). It was decided to use a "per-protocol" analysis as the excluded patients were either not eligible to fulfil the protocol, failed to comply with treatment or moved to another hospital or practice. In addition, most of the drop-outs had neither completed treatment nor reached a stage where outcomes could be predicted from the available baseline data, so imputing their data

could result in bias. Finally, the analysed sample size for the secondary outcomes investigated in the current article was found to be more than adequately powered (90.0%). Moreover, baseline characteristics of the drop-out participants and the sample analysed were found to be almost similar. The hypothesis investigated was that there is no significant difference between the 0.018-inch or 0.022-inch slot bracket systems in terms of (1) severity of OIIRR (2) patient perception of pain during treatment.

### *Severity of OIIRR*

In the current study the biological side effects of fixed appliance orthodontic treatment was evaluated by assessing the severity of OIIRR affecting the maxillary central incisors after 9 months from inserting the initial continuous archwire. The results of the current study did not reveal a statistically significant difference between the 0.018-inch and 0.022-inch slot brackets for OIIRR.

Evaluation of OIIRR in the current sample was undertaken by assessing the severity of OIIRR affecting the maxillary central incisors as they have the highest prevalence of OIIRR {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1043/0003-3219(2002)072<0180:OIIRRP>2.0.CO;2", "ISBN" : "0003-3219 (Print)\n0003-3219 (Linking)", "ISSN" : "00033219", "PMID" : "11999942", "abstract" : "Over the past 10 years, orthodontically induced inflammatory root resorption (OIIRR) has been increasingly recognized as an iatrogenic consequence of orthodontic treatment. With this in mind, orthodontists should take all known measures to reduce the occurrence of OIIRR. The evidence that we present in this review suggests several procedures known today that can avert this phenomenon; however, none of them can be relied on to completely prevent OIIRR. We believe that future studies might clarify the exact cause and course of OIIRR and, hopefully, help eliminate it. In Part I, we discussed the basic sciences aspects of OIIRR; in Part II, we present the clinical aspects of this phenomenon.", "author" : [ { "dropping-particle" : "", "family" : "Brezniak", "given" : "Naphtali", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Wasserstein", "given" : "Atalia", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "Angle Orthodontist", "id" : "ITEM-1", "issue" : "2", "issued" : { "date-parts" : [ [ "2002" ] ] }, "page" : "180-184", "title" : "Orthodontically Induced Inflammatory Root Resorption. Part II: The Clinical Aspects", "type" : "article", "volume" : "72" }, { "uris" : [ "http://www.mendeley.com/documents/?uuiid=89b4e744-87dd-4a10-92e2-6aa57ae7c6e3" ] }, { "id" : "ITEM-2", "itemData" : { "DOI" : "10.1016/j.ajodo.2009.06.021", "ISBN" : "1097-6752 (Electronic)\r0889-5406 (Linking)", "ISSN" : "1097-6752", "PMID" : "20362905", "abstract" : "INTRODUCTION: This systematic review evaluated root resorption as an outcome for patients who had orthodontic tooth movement. The results could provide the best available evidence for clinical decisions to minimize the risks and severity of root resorption. METHODS: Electronic databases were searched, nonelectronic journals were hand searched, and experts in the field were consulted with no language restrictions. Study selection criteria included randomized clinical trials involving human subjects for orthodontic tooth movement, with fixed appliances, and root resorption recorded during or after treatment. Two authors independently reviewed and extracted data from the selected studies on a standardized form. RESULTS: The searches retrieved 921 unique citations. Titles and abstracts identified 144 full articles from which 13 remained after the inclusion criteria were applied. Differences in the methodologic approaches and reporting results made quantitative statistical comparisons impossible. Evidence suggests that comprehensive orthodontic treatment causes increased incidence and severity of root resorption, and heavy forces might be particularly harmful. Orthodontically induced inflammatory root resorption is unaffected by archwire sequencing, bracket prescription, and self-ligation. Previous trauma and tooth morphology are unlikely causative factors. There is some evidence that a 2 to 3 month pause in treatment decreases total root resorption. CONCLUSIONS: The results were inconclusive in the clinical management of root resorption, but there is evidence to support the use of light forces, especially with incisor intrusion.", "author" : [ { "dropping-particle" : "", "family" : "Weltman", "given" : "B", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Vig", "given" : "K W", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], { "dropping-particle" : "", "family" : "Fields", "given" : "H W", "non-dropping-particle" : "" },





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A randomized clinical trial", "type": "article-journal", "volume": "28", "uris": [ "http://www.mendeley.com/documents/?uuid=272f992b-ee04-42a6-a000-1c55e86f7613" ] ], { "id": "ITEM-2", "itemData": { "DOI": "10.1093/ejo/cjl090", "ISBN": "0141-5387 (Print)\r0141-5387 (Linking)", "ISSN": "01415387", "PMID": "17229789", "abstract": "External apical root resorption (EARR) is an undesirable consequence of orthodontic treatment. The purpose of this study was to measure the amount of EARR and to examine its clinical significance in maxillary incisors, during a 12-month active treatment period. A further aim was to examine the contribution of gender, treatment technique, treatment duration, and extraction of maxillary first premolars to EARR. The sample comprised 151 maxillary incisor teeth in 40 patients (16 males, 24 females) aged 12-22 years, with different malocclusions. Standard periapical radiographs, using the long-cone paralleling technique, were obtained before and 6 and 12 months after the start of treatment. Quantitative measurements for 80 central and 71 lateral maxillary incisors were performed separately and corrected for image distortion. Root length reduction was calculated in millimetres and in terms of the percentage of the original root length. Resorption of more than 1 mm at 12 months of active treatment was considered to be clinically significant. On average, the degree of EARR for the maxillary central incisors was 0.77 +/- 0.42 and 1.67 +/- 0.64 mm, respectively, during the 6- and 12-month follow-up (P < 0.001). For the lateral incisors, the degree of EARR was 0.88 +/- 0.51 and 1.79 +/- 0.66 mm, respectively (P < 0.001). Clinically significant resorption was found for 74 per cent of the centrals and 82 per cent of the laterals. No significant correlation was observed between EARR and treatment technique. EARR was found to be correlated with gender for the lateral incisors. The effect of treatment duration (P < 0.001) and premolar extraction (P < 0.001) was statistically significant for both tooth groups.", "author": [ { "dropping-particle": "", "family": "Mohandesan", "given": "Hooman", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Ravanmehr", "given": "Hossein", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Valaei", "given": "Nasser", "non-dropping-particle": "", "parse-names": false, "suffix": "" } ], "container-title": "European Journal of Orthodontics", "id": "ITEM-2", "issue": "2", "issued": { "date-parts": [ [ "2007" ] ] }, "page": "134-139", "title": "A radiographic analysis of external apical root resorption of maxillary incisors during active orthodontic treatment", "type": "article-journal", "volume": "29", "uris": [ "http://www.mendeley.com/documents/?uuid=2aaf4e0c-2d14-4608-8f3b-f887667196d3" ] ], { "id": "ITEM-3", "itemData": { "DOI": "10.1043/0003-3219(2005)75[919:ARRSAM]2.0.CO;2", "ISBN": "1097-6752 (Electronic)\r0889-5406 (Linking)", "ISSN": "0003-3219", "PMID": "16448232", "abstract": "The low explained variance of identified risk factors for apical root resorption in orthodontic patients suggests effects of parameters related to individual predisposition. Our purpose was to explore this hypothesis. We evaluated standardized periapical radiographs of the maxillary incisors made before treatment (T1) as well as at about six and 12 months after bracket placement (T2 and T3) of 247 patients aged 10.1 to 57.1 years at T1. The radiographs were converted to digital images, and commercially available software was used to correct for differences in projection. The results showed that 20.2%, 7.7%, and 5.3% of the patients had > or =1 tooth with >2.0, 3.0, and 4.0 mm resorption at T3, respectively. Pearson's correlation revealed an association between resorption from T1 to T2 and from T2 to T3 (P < .01). The risk of > or =1 tooth with >1.0 mm resorption from T2 to T3 was 3.8 times higher (95% CI 2.4-6.0) in patients with > or =1 tooth with >1.0 mm from T1 to T2 than in those without. Also, resorption was more pronounced (P < .001) from T2 to T3 in patients with > or =1 tooth with >1.0 mm and >2.0 resorption from T1 to T2 than in those without. The explained variance of identified risk factors was <10%. Orthodontic patients with detectable root resorption during the first six months of active treatment are more likely to experience resorption in the following six-month period than those without.", "author": [ { "dropping-particle": "", "family": "Artun", "given": "Jon", "non-dropping-particle": "", "parse-

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Periapical radiographs were used in the current study to assess OIIRR as these are the routine gold standard conventional radiograph for detecting OIIRR {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1043/0003-3219(2001)071<0185:AORRAR>2.0.CO;2", "ISBN" : "0003-3219 (Print)\r0003-3219 (Linking)", "ISSN" : "00033219", "PMID" : "11407770", "abstract" : "A radiographic examination is an essential part of the diagnostic process in orthodontics. However, what radiographs are needed to properly evaluate root shape and position? Most clinicians order panoramic or periapical radiographs in addition to the cephalometric radiograph. The purpose of this study was to find out whether one type of film is more accurate than the other in the pretreatment evaluation of root shape and the posttreatment computation of apical root resorption. Pretreatment and posttreatment panoramic films and full-mouth periapical films from 42 patients who completed fixed orthodontic treatment were assessed for tooth length and root shape. Panoramic films showed significantly greater average apical root resorption than periapical films for the 743 teeth surveyed. The greatest differences were found in the lower incisors, the least in the maxillary incisors. Classification of root shape was significantly different between the 2 types of radiographs. Root dilacerations and other abnormal shapes, clearly visible on periapical films, often appeared normal on panoramic films. The findings strongly suggest that root shape is much harder to assess on panoramic films. We conclude that, in cases where the apices are obscured or other factors are present that might suggest higher risk for root resorption or vertical bone loss, periapical films should be ordered. The use of panoramic films to measure pre- and posttreatment root resorption may overestimate the amount of root loss by 20% or more.", "author" : [ { "dropping-particle" : "", "family" : "Sameshima", "given" : "Glenn T.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Asgarifar", "given" : "Kati O.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "Angle Orthodontist", "id" : "ITEM-1", "issue" : "3", "issued" : { "date-parts" : [ [ "2001" ] ] }, "page" : "185-189", "title" : "Assessment of Root Resorption and Root Shape: Periapical vs Panoramic Films", "type" : "article-journal", "volume" : "71" }, "uris" : [ "http://www.mendeley.com/documents/?uuid=cf36002f-3070-42ce-a338-bf36a54f2856" ] } }, "mendeley" : { "formattedCitation" : "(30)", "plainTextFormattedCitation" : "(30)", "previouslyFormattedCitation" : "(30)", "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } }.

Although periapical radiographs have been criticised for limited diagnostic information when compared to cone-beam CT imaging (CBCT), the relative increased radiation dose from CBCT could not be justified to detect any minimal differences in OIIRR, affecting the labial or palatal surfaces of the maxillary incisors, particularly where these differences are not clinically significant {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1111/j.1600-0722.2008.00559.x", "ISBN" : "1600-0722 (Electronic)\r0909-8836 (Linking)", "ISSN" : "09098836", "PMID" : "18821990", "abstract" : "The aim of this study was to validate the use of digitized periapical radiographs in evaluating orthodontically induced apical root resorption against micro-computed tomography (micro-CT) scanning as a criterion standard test. In a standardized experimental protocol, 29 premolars in 16 subjects were tipped buccally for 8 wk. Nineteen contralateral premolars not subjected to orthodontic movement served as controls. Standardized

periapical radiographs were taken before and after the experimental period (Rx method). These teeth were extracted and scanned using a micro-CT technique with a 9 µm resolution. Two calibrated examiners assessed blindly the presence or absence of apical root resorption on digitized radiographs and three-dimensional reconstructions of the scans. Significant differences were detected between the orthodontically moved teeth and controls: 86% of the orthodontically moved teeth and 21% of the control teeth showed apical root resorption when using micro-CT as a validation method. A total of 55% of the experimental teeth and 5% of the control teeth showed resorption when assessed using Rx method. The Rx method showed a specificity of 78% and a sensitivity of 44%, which means that less than half of the cases with root resorption identified using a CT scanner were identified by radiography. Nearly all the orthodontically moved teeth showed apical root resorption. Apical root resorption may be underestimated when evaluated using digitized periapical radiographs.", "author" : [ { "dropping-particle" : "", "family" : "Dudic", "given" : "Alexander", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Giannopoulou", "given" : "Catherine", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Martinez", "given" : "Manuela", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Montet", "given" : "Xavier", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Kiliaridis", "given" : "Stavros", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "European Journal of Oral Sciences", "id" : "ITEM-1", "issue" : "5", "issued" : { "date-parts" : [ [ "2008" ] ] }, "page" : "467-472", "title" : "Diagnostic accuracy of digitized periapical radiographs validated against micro-computed tomography scanning in evaluating orthodontically induced apical root resorption", "type" : "article-journal", "volume" : "116" }, "uris" : [ "http://www.mendeley.com/documents/?uuid=94640fcc-80f7-46b1-beae-3d810973463b" ] } ], "mendeley" : { "formattedCitation" : "(31)", "plainTextFormattedCitation" : "(31)", "previouslyFormattedCitation" : "(31)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } }.

Several techniques have been described in the literature for radiographically quantifying OIRR including linear measurements, scoring indices and digital image reconstruction {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1016/0002-9416(82)90317-7", "ISBN" : "0002-9416 (Print)\r0002-9416 (Linking)", "ISSN" : "00029416", "PMID" : "6961819", "abstract" : "This study concerns the frequency and degree of root resorption in traumatized incisors that have been treated orthodontically. The subjects were twenty-seven patients (fifteen boys and twelve girls) with fifty-five traumatized incisors; fifty-five consecutive patients without traumatized teeth served as controls. All the control patients were treated with extraction of four first premolars and a fixed appliance (thirty-three with an edgewise and twenty-two with a Begg appliance). Signs of root resorption were registered with index scores from 0 to 4 (Fig. 1). The degree of root resorption in traumatized teeth was compared to that in the uninjured control teeth in the same patient and in the patients without trauma. Neither the intraindividual nor the interindividual comparisons support the hypothesis that traumatized teeth have a greater tendency toward root resorption than uninjured teeth. Root resorption (scores 2 to 4) was found in 51 percent of the traumatized incisors, in 43 percent of the incisors treated with edgewise appliances, and in 48 percent of those treated with Begg appliances. Traumatized teeth with signs of root resorption prior to orthodontic treatment may be more prone to root resorption during treatment. \u00a9 1982.", "author" : [ { "dropping-particle" : "", "family" : "Malmgren", "given" : "Olle", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Goldson", "given" : "Lars", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Hill", "given" : "Carsten", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Orwin", "given" : "Anders", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Petrini", "given" : "Lars", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Lundberg", "given" : "Margareta", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ]

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 832X (Linking)", "ISSN" : "0250832X", "PMID" : "17463096", "abstract" : "OBJECTIVES: The
 purpose of this study was to develop an alternative diagnostic tool for the early detection of external
 apical root resorption (EARR). METHODS: Mandibular incisors (n=36) with and without simulated
 EARR lesions were used. 18 teeth with facial and proximal windows, each with a range of 2 sizes,
 were placed in 6 N hydrochloric acid (HCl) baths for 10 min. A sample of the acid solution was
 analysed for calcium concentration by atomic absorption spectrophotometry. Incisors were imaged at
 80 degrees, 90 degrees and 100 degrees under 3 test conditions (bracketed, non-bracketed and with
 subtraction registration templates (SRTs)). The images were reconstructed and subtracted to
 determine the accuracy and sensitivity of the method. Quantified histograms for each subtracted
 image were constructed. RESULTS: At either an angle of 80 degrees or 100 degrees, the bracketed
 group had the largest mean standard deviation of the subtraction histograms while the SRT group had
 the smallest. Density values as a function of total calcium removed were plotted indicating a linear
 relationship between subtraction density units and calcium loss. CONCLUSION: The use of the SRTs
 was significantly more accurate than the use of the brackets alone for digital subtraction radiography
 reconstructions. This model shows promise for detecting EARR prior to a noticeable decrease in root
 length. It may be useful for early detection of resorptive lesions during routine orthodontic
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 (Linking)", "ISSN" : "01415387", "PMID" : "8062862", "abstract" : "The aim of the investigation was
 to evaluate the effect of a treatment pause on teeth in which apical root resorption was discovered
 after an initial treatment period of 6 months with fixed appliance. Forty patients with initial apical
 root resorption in 62 upper incisors were included in the study. In 20 patients treatment continued
 according to the original plan and in 20 patients active treatment was interrupted during a pause of 2-3
 months. After the pause active treatment was resumed. Assessment of apical root resorption was
 performed on standardized radiographs taken with individual film holders. The amount of root
 resorption was significantly less in patients treated with a pause than in those treated without
 interruption.", "author" : [ { "dropping-particle" : "", "family" : "Levander", "given" : "Eva", "non-
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"https://github.com/citation-style-language/schema/raw/master/csl-citation.json" }}. It has been  
reported that even with adequate standardisation of the radiographic technique for consecutive  
periapical radiographs, potential errors in linear measurements of OIIRR can still occur due to several  
factors including change in the angulation of teeth during orthodontic tooth movement {ADDIN  
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3219(2004)074<0786:ACOTMT>2.0.CO;2", "ISBN" : "0003-3219", "ISSN" : "00033219", "PMID" :  
"15673142", "abstract" : "Measuring the severity of root shortening after orthodontic treatment is a  
common problem in the dental fields as well as in litigation, legislation, and the ethics arena. The  
most common method to evaluate root length shortening is by using periapical radiographs.  
Surprisingly, root elongation after orthodontic treatment in adult patients was reported in the past. The  
aims of this study were to measure the effects of angular changes between the tooth and the film on  
the length of the image of a tooth model, to compare three methods to accurately measure root length  
in different films, and to find the most accurate reference points on the tooth for calculating root  
lengths. Five amalgam dots were placed on an acrylic model of a maxillary central incisor: ie, most  
apical, most incisal, mesial CEJ, distal CEJ, and most apical CEJ on the buccal side. The tooth model  
was placed in a special jig and radiographed at four different film-to-tooth angulations. Root and  
crown lengths were measured on both the model itself and on a computer monitor displaying the  
image that resulted from scanning the film into the computer. The results revealed that angular  
changes between the tooth and the film affect the measured tooth length. The midpoint between the  
mesial CEJ point and the distal CEJ point (median CEJ) was the best reference point for measuring  
root length. This was true when the calculations were done with the rule-of-three formula.", "author" :  
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with several studies {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : {  
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"ISSN" : "0889-5406", "PMID" : "8154460", "abstract" : "Of the several modes of tooth movement,  
pressure from intrusive forces seems the most likely to cause external apical root resorption (EARR).  
This has been demonstrated for incisors in human beings and molars in laboratory animals. The  
present study examined full-banded adolescent patients and scored the degrees of in-treatment root  
resorption throughout the dentition. Just Class I cases with four first premolar extractions were used.  
Equal samples of conventional Begg and Tweed treated cases were examined with 1:1 sex ratios (total  
n = 83). No difference between the Begg and Tweed techniques and no sex difference was found in  
any of the 30 univariate tests, even though power analysis indicated a strong likelihood of finding a

difference if one existed. By using multiple linear regression, significant decreases in length (EARR) were found for those roots systematically intruded in this Class I malocclusion, notably the mesial root of the maxillary first molar and the distal root of the mandibular first molar. Even though some of the present cases had been in \"active\" treatment up to 6 years, we found no significant association between duration of treatment and degree or amount of EARR.

**author** : [ { "dropping-particle" : "", "family" : "Beck", "given" : "B W", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Harris", "given" : "E F", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics", "id" : "ITEM-1", "issue" : "4", "issued" : { "date-parts" : [ [ "1994" ] ] }, "page" : "350-61", "title" : "Apical root resorption in orthodontically treated subjects: analysis of edgewise and light wire mechanics.", "type" : "article-journal", "volume" : "105" }, "uris" : [ "http://www.mendeley.com/documents/?uid=2e7a1ce4-8341-4df5-8d0a-8aee03786bd2" ] }, { "id" : "ITEM-2", "itemData" : { "DOI" : "10.2319/061311-390.1", "ISSN" : "1945-7103", "PMID" : "21919826", "abstract" : "OBJECTIVE: To investigate the incidence and severity of root resorption during orthodontic treatment by means of cone beam computed tomography (CBCT) and to explore factors affecting orthodontically induced inflammatory root resorption (OIIRR).\\n\\nMATERIALS AND METHODS: CBCT examinations were performed on 152 patients with Class I malocclusion. All roots from incisors to first molars were assessed on two or three occasions.\\n\\nRESULTS: At treatment end, 94% of patients had \\u22651 root with shortening >1 mm, and 6.6% had \\u22651 tooth where it exceeded 4 mm. Among teeth, 56.3% of upper lateral incisors had root shortening >1 mm. Of upper incisors and the palatal root of upper premolars, 2.6% showed root shortenings >4 mm. Slanted surface resorptions of buccal and palatal surfaces were found in 15.1% of upper central and 11.5% of lateral incisors. Monthly root shortening was greater after 6-month control than before. Upper jaw teeth and anterior teeth were significantly associated with the degree of root shortening. Gender, root length at baseline, and treatment duration were not.\\n\\nCONCLUSION: Practically all patients and up to 91% of all teeth showed some degree of root shortening, but few patients and teeth had root shortenings >4 mm. Slanted root resorption was found on root surfaces that could be evaluated only by a tomographic technique. A CBCT technique can provide more valid and accurate information about root resorption.", "author" : [ { "dropping-particle" : "", "family" : "Lund", "given" : "Henrik", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Gr\u00f6ndahl", "given" : "Kerstin", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Hansen", "given" : "Ken", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Gr\u00f6ndahl", "given" : "Hans-G\u00f6ran", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "The Angle orthodontist", "id" : "ITEM-2", "issue" : "3", "issued" : { "date-parts" : [ [ "2012" ] ] }, "page" : "480-7", "title" : "Apical root resorption during orthodontic treatment. A prospective study using cone beam CT.", "type" : "article-journal", "volume" : "82" }, "uris" : [ "http://www.mendeley.com/documents/?uid=ecdde7f8-eccb-4554-86ba-673945765647" ] } ], "mendeley" : { "formattedCitation" : "(26,35)", "plainTextFormattedCitation" : "(26,35)", "previouslyFormattedCitation" : "(26,35)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } } to use the OIIRR scoring index suggested by Malmgren et al. {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1016/0002-9416(82)90317-7", "ISBN" : "0002-9416 (Print)\\r0002-9416 (Linking)", "ISSN" : "00029416", "PMID" : "6961819", "abstract" : "This study concerns the frequency and degree of root resorption in traumatized incisors that have been treated orthodontically. The subjects were twenty-seven patients (fifteen boys and twelve girls) with fifty-five traumatized incisors; fifty-five consecutive patients without traumatized teeth served as controls. All the control patients were treated with extraction of four first premolars and a fixed appliance (thirty-

three with an edgewise and twenty-two with a Begg appliance). Signs of root resorption were registered with index scores from 0 to 4 (Fig. 1). The degree of root resorption in traumatized teeth was compared to that in the uninjured control teeth in the same patient and in the patients without trauma. Neither the intraindividual nor the interindividual comparisons support the hypothesis that traumatized teeth have a greater tendency toward root resorption than uninjured teeth. Root resorption (scores 2 to 4) was found in 51 percent of the traumatized incisors, in 43 percent of the incisors treated with edgewise appliances, and in 48 percent of those treated with Begg appliances. Traumatized teeth with signs of root resorption prior to orthodontic treatment may be more prone to root resorption during treatment.

1982.", "author" : [ { "dropping-particle" : "", "family" : "Malmgren", "given" : "Olle", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Goldson", "given" : "Lars", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Hill", "given" : "Carsten", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Orwin", "given" : "Anders", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Petrini", "given" : "Lars", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Lundberg", "given" : "Margareta", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "American Journal of Orthodontics", "id" : "ITEM-1", "issue" : "6", "issued" : { "date-parts" : [ [ "1982" ] ] }, "page" : "487-491", "title" : "Root resorption after orthodontic treatment of traumatized teeth", "type" : "article-journal", "volume" : "82" }, "uris" : [ "http://www.mendeley.com/documents/?uid=f98421e0-afe0-4a38-88b4-4b26d1faad42" ] }, "mendeley" : { "formattedCitation" : "(20)", "plainTextFormattedCitation" : "(20)", "previouslyFormattedCitation" : "(19)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } } was used. The use of this index avoided error from linear measurements. Although the scoring index may be slightly subjective depending on morphological root changes in combination with measurement guidance, the high intra- and inter examiner agreement of the OIIRR scores suggests high reliability of the results (0.938 and 0.749 respectively). Assessment of OIIRR at 9 months as a representative period is in line with the British Orthodontic Society radiography guidelines {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1016/j.ajodo.2015.10.014", "ISSN" : "0889-5406", "abstract" : "Tel: +44 (0)20 7353 8680 Fax: +44 (0)20 7353 8682 www.bos.org.uk British Library Cataloguing Data A catalogue record for this book is available from the British Library ISBN 1 899297 09 X X 2 IN 1994 The British Society for the Study of Orthodontics (BSSO) asked the Standards Committee to develop guidelines for the use of radiographs in orthodontics, which formed the basis for the first edition. This was one of the first published sets of guidelines for dentistry. The initial work done by the members of the Committee has been the basis for further editions. In 2000 the Ionising Radiation (Medical Exposure) Regulations (IRMER) 1 were published and these were incorporated into the subsequent editions. The need for a fourth edition is due to the increasing availability of Cone Beam Computed Tomography (CBCT) which usually enables dento-maxillofacial imaging with a lower exposure than conventional CT. Such machines are now readily available and are being promoted as 3D imaging techniques for the teeth and jaws. Some orthodontists are using them as part of orthodontic treatment planning and, although the exposure is usually less than a conventional CT, it can be at least 20 times greater than normal dental radiography. 2 CBCT imaging has a useful place in selected cases and European evidence-based guidelines for their use have been formulated by the SEDENTEXCT project. 3 In this edition a new section on CBCT has been added which takes these European guidelines into account and discusses their place in orthodontic treatment. The majority of changes in this fourth edition are due to the expertise of the dental and maxillofacial radiologists", "author" : [ { "dropping-particle" : "", "family" : "Isaacson", "given" : "K G", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Thom", "given" : "A R", "non-dropping-particle" : "", "parse-names" : false,



"suffix" : "" }, { "dropping-particle" : "", "family" : "Horner", "given" : "K", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Whaites", "given" : "E", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "British Orthodontic Society", "id" : "ITEM-1", "issue" : "0", "issued" : { "date-parts" : [ [ "2015" ] ] }, "number-of-pages" : "1-28", "title" : "Guidelines for the use of radiographs in clinical orthodontics", "type" : "book" }, "uris" : [ "http://www.mendeley.com/documents/?uuid=a667ddfd-be02-4de1-aae4-b7ea187e91c4" ] } ], "mendeley" : { "formattedCitation" : "(18)", "plainTextFormattedCitation" : "(18)", "previouslyFormattedCitation" : "(18)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } } where severe OIIRR can be detected early in treatment by radiographically assessing the maxillary incisors 6 to 9 months from start of treatment. This is also in accordance with several investigations that have reported OIIRR is detectable at least six months from start of treatment {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1093/ejo/10.1.30", "ISBN" : "0141-5387", "ISSN" : "0141-5387", "PMID" : "3162877", "abstract" : "The purpose of the study was to investigate the risk of severe apical root resorption after orthodontic treatment with fixed appliances in relation to resorption after initial treatment, 6-9 months; and in relation to apical root form. The risk of severe apical root resorption in relation to resorption after 6-9 months of treatment was studied on 390 upper incisors in 98 consecutive patients (55 boys, 43 girls). Intra-oral radiographs before treatment, after 6-9 months and after treatment were evaluated. The importance of the root form (normal, short, blunt, apically bent, pipette shaped) for root resorption was studied on 610 upper incisors in 153 patients (75 boys, 78 girls). Intra-oral radiographs before and after treatment were evaluated. Treatment was performed with an edgewise or a Begg technique and lasted from 11 to 29 months. An index from 0 to 4 (Fig. 1) was used for the evaluation of the degree of root resorption. Root resorption after treatment was significantly related to the resorption after the initial 6-9 months. The results indicate a risk of severe resorption in teeth with minor resorptions after 6-9 months. Even an irregular root contour after 6-9 months indicates a risk of severe resorption. No-severe resorption was found after treatment in teeth without resorption after 6-9 months. The degree of root resorption in teeth with blunt or pipette shaped roots was significantly higher than in teeth with a normal root form.", "author" : [ { "dropping-particle" : "", "family" : "Levander", "given" : "E.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Malmgren", "given" : "O.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "The European Journal of Orthodontics", "id" : "ITEM-1", "issue" : "1", "issued" : { "date-parts" : [ [ "1988" ] ] }, "page" : "30-38", "title" : "Evaluation of the risk of root resorption during orthodontic treatment: A study of upper incisors", "type" : "article-journal", "volume" : "10" }, "uris" : [ "http://www.mendeley.com/documents/?uuid=ca47d8eb-aeb9-4037-9bc7-dd444908d7cf" ] } ], { "id" : "ITEM-2", "itemData" : { "ISBN" : "0141-5387 (Print)", "ISSN" : "0141-5387 (Linking)", "ISSN" : "0141-5387", "PMID" : "9753824", "abstract" : "The aim of this study was to evaluate the risk of root resorption during orthodontic treatment of patients with aplasia, and to analyse the relative importance of some anamnestic and treatment variables. The subjects comprised 68 orthodontically treated patients with 1-16 congenitally missing teeth. The age of the patients was 11-20 years (mean 15 years). All patients were treated with fixed edgewise appliances. The purpose of the orthodontic treatment varied: to create optimal conditions for prosthetic restorations or osseointegrated implants, or to achieve aesthetic and functional alignment of teeth in less severe cases. The degree of root resorption was assessed before and after treatment from intra-oral radiographs of the maxillary incisors using a scale of 0-4. In all, 186 maxillary incisors were evaluated. The degree of apical root resorption was significantly greater in cases of multiple aplasia (4-16 missing teeth) than in those with only one to three missing teeth. Root form, treatment time with rectangular wires and intermaxillary elastics, and total treatment time were significantly related to root resorption. Discriminant analysis disclosed that the following variables were the most important determinants of root resorption: number of missing teeth, root form, and time with rectangular archwires and intermaxillary elastics. It

is concluded that there is a high risk of apical root resorption during orthodontic treatment in patients with multiple aplasia (four or more teeth), in particular in teeth with an abnormal root form and lengthy treatment with elastics and rectangular archwires.", "author" : [ { "dropping-particle" : "", "family" : "Levander", "given" : "E", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Malmgren", "given" : "O", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Stenback", "given" : "K", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "European journal of orthodontics", "id" : "ITEM-2", "issued" : { "date-parts" : [ [ "1998" ] ] }, "page" : "427-434", "title" : "Apical root resorption during orthodontic treatment of patients with multiple aplasia: a study of maxillary incisors.", "type" : "article-journal", "volume" : "20" }, "uris" : [ "http://www.mendeley.com/documents/?uuid=22cf4910-56ba-477b-8d49-1a08b216c991" ] }, { "id" : "ITEM-3", "itemData" : { "DOI" : "10.1016/j.ajodo.2003.12.030", "ISSN" : "0889-5406 (Print)", "PMID" : "16027626", "abstract" : "INTRODUCTION: Individual predisposition might be a major reason for the observed variation in apical orthodontic root resorption. If so, resorption might be expressed during the initial stages of orthodontic therapy in patients at risk. METHODS: To explore this hypothesis, we evaluated standardized, digitized periapical radiographs made before treatment (T1) and at a mean period of 6.4 months (SD 0.9) after placement of maxillary incisor brackets (T2) in 290 patients (age range, 10.1 to 57.1 years at T1). Anamnestic and treatment parameters were recorded according to a protocol, and maxillary incisor irregularity was measured on T1 study models. RESULTS: The mean average root resorption for 4 incisors was 0.53 mm (SD 0.47), whereas the sample mean of the most severely resorbed tooth per patient was 1.18 mm (SD 0.86). A total of 4.1% of the patients had an average resorption of 1.5 mm or more, and 15.5% had at least 1 tooth with 2.0 mm or more resorption. The maximum amount of resorption was 4.4 mm. Multivariate linear regression showed that deviated root form and increased T1-to-T2 time period were risk factors for apical root resorption of the central incisors; normal root form and wide roots were preventive factors, with an explained variance of 14%. Similarly, long roots, narrow roots, and increased T1-to-T2 time period were risk factors for resorption of the lateral incisors, whereas normal root form was a preventive factor, with an explained variance of 24%. Parameters associated with use of rectangular wire, presence of incisor irregularity, and history of trauma were not identified as risk factors. Use of elastics was not included in the regression analyses. CONCLUSIONS: Root resorption can begin in the early leveling stages of orthodontic treatment. About 4.1% of patients studied had an average resorption of 1.5 mm or more of the 4 maxillary incisors, and about 15.5% had 1 or more maxillary incisors with resorption of 2.0 mm or more from 3 to 9 months after initiation of fixed appliance therapy. Although teeth with long, narrow, and deviated roots are at increased risk of resorption during this early stage, the explained variance of these risk factors is less than 25%.", "author" : [ { "dropping-particle" : "", "family" : "Smale", "given" : "Isolde", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Artun", "given" : "Jon", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Behbehani", "given" : "Faraj", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Doppel", "given" : "Diane", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "van't Hof", "given" : "Martin", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Kuijpers-Jagtman", "given" : "Anne M", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics", "id" : "ITEM-3", "issue" : "1", "issued" : { "date-parts" : [ [ "2005" ] ] }, "page" : "57-67", "title" : "Apical root resorption 6 months after initiation of fixed orthodontic appliance therapy.", "type" : "article-journal", "volume" : "128" }, "uris" : [ "http://www.mendeley.com/documents/?uuid=39ee6d79-cd35-4b4f-8ecc-464a75ccf518" ] }, { "id" : "ITEM-4", "itemData" : { "DOI" : "10.1043/0003-3219(2005)75[919:ARRSAM]2.0.CO;2", "ISBN" :

"1097-6752 (Electronic)\r0889-5406 (Linking)", "ISSN" : "0003-3219", "PMID" : "16448232", "abstract" : "The low explained variance of identified risk factors for apical root resorption in orthodontic patients suggests effects of parameters related to individual predisposition. Our purpose was to explore this hypothesis. We evaluated standardized periapical radiographs of the maxillary incisors made before treatment (T1) as well as at about six and 12 months after bracket placement (T2 and T3) of 247 patients aged 10.1 to 57.1 years at T1. The radiographs were converted to digital images, and commercially available software was used to correct for differences in projection. The results showed that 20.2%, 7.7%, and 5.3% of the patients had > or =1 tooth with >2.0, 3.0, and 4.0 mm resorption at T3, respectively. Pearson's correlation revealed an association between resorption from T1 to T2 and from T2 to T3 (P < .01). The risk of > or =1 tooth with >1.0 mm resorption from T2 to T3 was 3.8 times higher (95% CI 2.4-6.0) in patients with > or =1 tooth with >1.0 mm from T1 to T2 than in those without. Also, resorption was more pronounced (P < .001) from T2 to T3 in patients with > or =1 tooth with >1.0 mm and >2.0 resorption from T1 to T2 than in those without. The explained variance of identified risk factors was <10%. Orthodontic patients with detectable root resorption during the first six months of active treatment are more likely to experience resorption in the following six-month period than those without.", "author" : [ { "dropping-particle" : "", "family" : "Artun", "given" : "Jon", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Smale", "given" : "Isolde", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Behbehani", "given" : "Faraj", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Doppel", "given" : "Diane", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Van't Hof", "given" : "Martin", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Kuijpers-Jagtman", "given" : "Anne M", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "The Angle orthodontist", "id" : "ITEM-4", "issue" : "6", "issued" : { "date-parts" : [ [ "2005" ] ] }, "page" : "919-26", "title" : "Apical root resorption six and 12 months after initiation of fixed orthodontic appliance therapy.", "type" : "article-journal", "volume" : "75" }, "uris" : [ "http://www.mendeley.com/documents/?uuid=4e3a45fd-4e55-4c5f-b95c-8cb5ef695394" ] }, "mendeley" : { "formattedCitation" : "(8,29,36,37)", "plainTextFormattedCitation" : "(8,29,36,37)", "previouslyFormattedCitation" : "(8,29,36,37)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } }.

There was a statistically significant increase in the severity of root resorption at 9 months of treatment for the total sample and in the two study groups. Almost three quarters (75.8%) of the sample in the current study showed some degree of OIIRR after 9 months from the start of orthodontic tooth movement. This relatively high percentage is in agreement with CBCT and histological studies reporting that almost all teeth experience a degree of OIIRR, although for most patients, OIIRR is considered clinically insignificant {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1016/j.ajodo.2009.06.021", "ISBN" : "1097-6752 (Electronic)\r0889-5406 (Linking)", "ISSN" : "1097-6752", "PMID" : "20362905", "abstract" : "INTRODUCTION: This systematic review evaluated root resorption as an outcome for patients who had orthodontic tooth movement. The results could provide the best available evidence for clinical decisions to minimize the risks and severity of root resorption. METHODS: Electronic databases were searched, nonelectronic journals were hand searched, and experts in the field were consulted with no language restrictions. Study selection criteria included randomized clinical trials involving human subjects for orthodontic tooth movement, with fixed appliances, and root resorption recorded during or after treatment. Two authors independently reviewed and extracted data from the selected studies on a standardized form. RESULTS: The searches retrieved 921 unique citations. Titles and abstracts identified 144 full articles from which 13 remained after the inclusion criteria were applied. Differences in the methodologic approaches and reporting results made quantitative statistical comparisons impossible. Evidence suggests that comprehensive orthodontic treatment causes increased incidence and severity of root resorption, and heavy forces might be particularly harmful.

Orthodontically induced inflammatory root resorption is unaffected by archwire sequencing, bracket prescription, and self-ligation. Previous trauma and tooth morphology are unlikely causative factors. There is some evidence that a 2 to 3 month pause in treatment decreases total root resorption.

**CONCLUSIONS:** The results were inconclusive in the clinical management of root resorption, but there is evidence to support the use of light forces, especially with incisor intrusion.", "author" : [ { "dropping-particle" : "", "family" : "Weltman", "given" : "B", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Vig", "given" : "K W", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Fields", "given" : "H W", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Shanker", "given" : "S", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Kaizar", "given" : "E E", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics", "id" : "ITEM-1", "issue" : "4", "issued" : { "date-parts" : [ [ "2010" ] ] }, "page" : "462-76; discussion 12A", "title" : "Root resorption associated with orthodontic tooth movement: a systematic review", "type" : "article-journal", "volume" : "137" }, "uris" : [ "http://www.mendeley.com/documents/?uuid=74bf74a7-056b-470e-aa38-ec8ac56e767e" ] }, "mendeley" : { "formattedCitation" : "(25)", "plainTextFormattedCitation" : "(25)", "previouslyFormattedCitation" : "(25)", "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } }.

There was no statistically significant difference in the severity of OIIRR between the 0.018 and 0.022 groups for the radiographs taken pre-treatment ( $P= 0.847$ ) and at 9 months from the start of treatment ( $P=0.115$ ). The difference in bracket slot size between the study groups allowed the use of larger dimension rectangular aligning archwires in combination with the 0.022-inch bracket slot system when compared with the 0.018 bracket slot system. This increase in archwire dimension and decrease in 'play' between the 0.018-inch bracket slot and the initial archwire (0.016 NiTi) can in turn increase orthodontic forces applied to teeth and lead to increased forces on the dentoalveolar process, respectively. However, the reduced working archwire dimensions (0.016 x 0.022 inch-stainless steel) According to the results from the current study this difference in the interaction between the different bracket slot systems and archwires had no significant influence on the severity of OIIRR.

Our results agree with those from a randomised clinical trial investigating the difference in severity of OIIRR between standard edgewise bracket system (0.018-inch slot) and pre-adjusted edgewise Roth prescription brackets (0.022-inch slot) {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "ISBN" : "1434-5293 (Print)\r1434-5293 (Linking)", "PMID" : "9577105", "abstract" : "The purpose of this paper was to compare radiographically the prevalence and degree of apical root resorption after treatment with a fully programmed edgewise appliance (FPA) and a partly programmed edgewise appliance (PPA) in a randomized multipractice clinical trial. Two groups of patients with Class II malocclusions were treated orthodontically. The type of treatment was randomly assigned by a computer program. During fixed appliance therapy, one group was treated according to the precepts of the straight wire concept (FPA; n = 32) while the other was treated with conventional full edgewise mechanics (PPA; n = 29). Treatment times were recorded. Radiographs of the maxillary incisors were made before and after active treatment with fixed appliances using the bisecting angle technique. To correct for different projecting angles the pairs of radiographs were digitally reconstructed. The prevalence and degree of root resorption were assessed. The mean treatment time was 1.8 years and 1.6 years for treatment with FPA and PPA, respectively. The mean amount of loss of tooth length was 8.2% for the patients treated with FPA and 7.5% for the patients treated with PPA. No statistically significant differences could be assessed between both groups at the end of active treatment. The mean prevalence of apical root resorption was 75% for the patients treated with FPA and 55% for the patients treated with PPA. Statistical evaluation showed no significant differences. We concluded that the prevalence and degree of root resorption is independent of the appliances as used in this study.", "author" : [ { "dropping-particle" : "", "family" : "Reukers",

"given" : "E A", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Sanderink", "given" : "G C", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Kuijpers-Jagtman", "given" : "A M", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "van't Hof", "given" : "M A", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "J Orofac Orthop", "id" : "ITEM-1", "issue" : "2", "issued" : { "date-parts" : [ [ "1998" ] ] }, "page" : "100-109", "title" : "Radiographic evaluation of apical root resorption with 2 different types of edgewise appliances. Results of a randomized clinical trial", "type" : "article-journal", "volume" : "59", "uris" : [ "http://www.mendeley.com/documents/?uuid=c267b8cc-e1c2-460b-a46b-32e3b21635c0" ] }, "mendeley" : { "formattedCitation" : "(11)", "plainTextFormattedCitation" : "(11)", "previouslyFormattedCitation" : "(11)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" }}. The authors found no statistically significant difference between the two groups; however, the bracket prescription could have been a potential confounding factor influencing the results. Moreover, Artun et al. [ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1043/0003-3219(2005)75[919:ARRSAM]2.0.CO;2", "ISBN" : "1097-6752 (Electronic)"\\r0889-5406 (Linking)", "ISSN" : "0003-3219", "PMID" : "16448232", "abstract" : "The low explained variance of identified risk factors for apical root resorption in orthodontic patients suggests effects of parameters related to individual predisposition. Our purpose was to explore this hypothesis. We evaluated standardized periapical radiographs of the maxillary incisors made before treatment (T1) as well as at about six and 12 months after bracket placement (T2 and T3) of 247 patients aged 10.1 to 57.1 years at T1. The radiographs were converted to digital images, and commercially available software was used to correct for differences in projection. The results showed that 20.2%, 7.7%, and 5.3% of the patients had > or =1 tooth with >2.0, 3.0, and 4.0 mm resorption at T3, respectively. Pearson's correlation revealed an association between resorption from T1 to T2 and from T2 to T3 (P < .01). The risk of > or =1 tooth with >1.0 mm resorption from T2 to T3 was 3.8 times higher (95% CI 2.4-6.0) in patients with > or =1 tooth with >1.0 mm from T1 to T2 than in those without. Also, resorption was more pronounced (P < .001) from T2 to T3 in patients with > or =1 tooth with >1.0 mm and >2.0 mm resorption from T1 to T2 than in those without. The explained variance of identified risk factors was <10%. Orthodontic patients with detectable root resorption during the first six months of active treatment are more likely to experience resorption in the following six-month period than those without.", "author" : [ { "dropping-particle" : "", "family" : "Artun", "given" : "Jon", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Smale", "given" : "Isolde", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Behbehani", "given" : "Faraj", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Doppel", "given" : "Diane", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Van't Hof", "given" : "Martin", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Kuijpers-Jagtman", "given" : "Anne M", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "The Angle orthodontist", "id" : "ITEM-1", "issue" : "6", "issued" : { "date-parts" : [ [ "2005" ] ] }, "page" : "919-26", "title" : "Apical root resorption six and 12 months after initiation of fixed orthodontic appliance therapy.", "type" : "article-journal", "volume" : "75", "uris" : [ "http://www.mendeley.com/documents/?uuid=4e3a45fd-4e55-4c5f-b95c-8cb5ef695394" ] } ], "mendeley" : { "formattedCitation" : "(29)", "plainTextFormattedCitation" : "(29)", "previouslyFormattedCitation" : "(29)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" }} and Smale et al. [ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1016/j.ajodo.2003.12.030", "ISSN" : "0889-5406 (Print)", "PMID" : "16027626", "abstract" : "INTRODUCTION: Individual predisposition might be a major reason for the observed variation in apical orthodontic root resorption. If so, resorption might be expressed during the initial stages of orthodontic therapy in patients at risk. METHODS: To explore this hypothesis, we evaluated standardized, digitized periapical radiographs made before treatment (T1) and at a mean period of 6.4 months (SD 0.9) after placement of maxillary incisor brackets (T2) in 290 patients (age range, 10.1 to 57.1 years at T1). Anamnestic and treatment parameters were recorded according to a protocol, and

maxillary incisor irregularity was measured on T1 study models. RESULTS: The mean average root resorption for 4 incisors was 0.53 mm (SD 0.47), whereas the sample mean of the most severely resorbed tooth per patient was 1.18 mm (SD 0.86). A total of 4.1% of the patients had an average resorption of 1.5 mm or more, and 15.5% had at least 1 tooth with 2.0 mm or more resorption. The maximum amount of resorption was 4.4 mm. Multivariate linear regression showed that deviated root form and increased T1-to-T2 time period were risk factors for apical root resorption of the central incisors; normal root form and wide roots were preventive factors, with an explained variance of 14%. Similarly, long roots, narrow roots, and increased T1-to-T2 time period were risk factors for resorption of the lateral incisors, whereas normal root form was a preventive factor, with an explained variance of 24%. Parameters associated with use of rectangular wire, presence of incisor irregularity, and history of trauma were not identified as risk factors. Use of elastics was not included in the regression analyses. CONCLUSIONS: Root resorption can begin in the early leveling stages of orthodontic treatment. About 4.1% of patients studied had an average resorption of 1.5 mm or more of the 4 maxillary incisors, and about 15.5% had 1 or more maxillary incisors with resorption of 2.0 mm or more from 3 to 9 months after initiation of fixed appliance therapy. Although teeth with long, narrow, and deviated roots are at increased risk of resorption during this early stage, the explained variance of these risk factors is less than 25%.

"author" : [ { "dropping-particle" : "", "family" : "Smale", "given" : "Isolde", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Artun", "given" : "Jon", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Behbehani", "given" : "Faraj", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Doppel", "given" : "Diane", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "van't Hof", "given" : "Martin", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Kuijpers-Jagtman", "given" : "Anne M", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics", "id" : "ITEM-1", "issue" : "1", "issued" : { "date-parts" : [ [ "2005" ] ] }, "page" : "57-67", "title" : "Apical root resorption 6 months after initiation of fixed orthodontic appliance therapy.", "type" : "article-journal", "volume" : "128" }, "uris" : [ "http://www.mendeley.com/documents/?uuiid=39ee6d79-cd35-4b4f-8ecc-464a75ccf518" ] }, "mendeley" : { "formattedCitation" : "(8)", "plainTextFormattedCitation" : "(8)", "previouslyFormattedCitation" : "(8)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } } using the same sample reported no statistically significant difference between the patients treated with 0.018 or 0.022 slots after 6 and 12 months from starting treatment; however the statistical tests were not reported in the published articles. Also, selection bias could have influenced the results due to a lack of random allocation on the level of the bracket slot size in these two studies.

It has been well documented that the aetiology of OIIRR is multifactorial including individual and treatment factors {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1043/0003-3219(2002)072<0180:OIIRRP>2.0.CO;2", "ISBN" : "0003-3219 (Print)\n0003-3219 (Linking)", "ISSN" : "00033219", "PMID" : "11999942", "abstract" : "Over the past 10 years, orthodontically induced inflammatory root resorption (OIIRR) has been increasingly recognized as an iatrogenic consequence of orthodontic treatment. With this in mind, orthodontists should take all known measures to reduce the occurrence of OIIRR. The evidence that we present in this review suggests several procedures known today that can avert this phenomenon; however, none of them can be relied on to completely prevent OIIRR. We believe that future studies might clarify the exact cause and course of OIIRR and, hopefully, help eliminate it. In Part I, we discussed the basic sciences aspects of OIIRR; in Part II, we present the clinical aspects of this phenomenon.", "author" : [ { "dropping-particle" : "", "family" : "Brezniak", "given" : "Naphtali", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Wasserstein", "given" : "Atalia", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "Angle Orthodontist", "id" : "ITEM-1", "issue" : "2", "issued" : { "date-parts" : [ [ "2002" ] ] }, "page" : "180-184", "title" : "Orthodontically Induced Inflammatory Root Resorption. Part II: The Clinical

Aspects", "type" : "article", "volume" : "72" }, "uris" : [ "http://www.mendeley.com/documents/?uuid=89b4e744-87dd-4a10-92e2-6aa57ae7c6e3" ] } ], "mendeley" : { "formattedCitation" : "(13)", "plainTextFormattedCitation" : "(13)", "previouslyFormattedCitation" : "(13)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" }}. The findings from the current study determined that the effect of bracket slot size on the severity of OIIRR is insignificant. This agrees with Weltman et al. {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1016/j.ajodo.2009.06.021", "ISBN" : "1097-6752 (Electronic)", "ISSN" : "1097-6752", "PMID" : "20362905", "abstract" : "INTRODUCTION: This systematic review evaluated root resorption as an outcome for patients who had orthodontic tooth movement. The results could provide the best available evidence for clinical decisions to minimize the risks and severity of root resorption. METHODS: Electronic databases were searched, nonelectronic journals were hand searched, and experts in the field were consulted with no language restrictions. Study selection criteria included randomized clinical trials involving human subjects for orthodontic tooth movement, with fixed appliances, and root resorption recorded during or after treatment. Two authors independently reviewed and extracted data from the selected studies on a standardized form. RESULTS: The searches retrieved 921 unique citations. Titles and abstracts identified 144 full articles from which 13 remained after the inclusion criteria were applied. Differences in the methodologic approaches and reporting results made quantitative statistical comparisons impossible. Evidence suggests that comprehensive orthodontic treatment causes increased incidence and severity of root resorption, and heavy forces might be particularly harmful. Orthodontically induced inflammatory root resorption is unaffected by archwire sequencing, bracket prescription, and self-ligation. Previous trauma and tooth morphology are unlikely causative factors. There is some evidence that a 2 to 3 month pause in treatment decreases total root resorption. CONCLUSIONS: The results were inconclusive in the clinical management of root resorption, but there is evidence to support the use of light forces, especially with incisor intrusion.", "author" : [ { "dropping-particle" : "", "family" : "Weltman", "given" : "B", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Vig", "given" : "K W", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Fields", "given" : "H W", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Shanker", "given" : "S", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Kaizar", "given" : "E E", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics", "id" : "ITEM-1", "issue" : "4", "issued" : { "date-parts" : [ [ "2010" ] ] }, "page" : "462-76; discussion 12A", "title" : "Root resorption associated with orthodontic tooth movement: a systematic review", "type" : "article-journal", "volume" : "137" }, "uris" : [ "http://www.mendeley.com/documents/?uuid=74bf74a7-056b-470e-aa38-ec8ac56e767e" ] } } ], "mendeley" : { "formattedCitation" : "(25)", "plainTextFormattedCitation" : "(25)", "previouslyFormattedCitation" : "(25)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" }} who reported in a systematic review that OIIRR is unaffected by archwire sequencing, bracket prescription, or design.

#### *Correlation between OIIRR and dental trauma:*

In the current trial 16.4% of the participants reported history of trauma to the upper anterior teeth. This percentage is similar to that reported by Brin et al. {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1093/ejo/13.5.372", "ISBN" : "0141-5387 (Print)", "ISSN" : "0141-5387", "PMID" : "1748184", "abstract" : "The reaction of previously traumatized teeth to orthodontic force application was investigated. Four groups of children were examined: group T comprised 56 children who encountered trauma to their maxillary incisors; group O comprised 29 orthodontic patients with intact incisors; group TO comprised 28 previously traumatized orthodontic patients; and group C served as the control group (n = 26). Orthodontic treatment was restricted to tipping movement executed only by means of removable appliances. Groups T, O, and TO were followed up longitudinally by means of clinical and

radiographic examinations. In most of the cases the reported trauma occurred to teeth with completed roots and affected the crown only. Group TO presented the highest, though relatively moderate, prevalence of root resorption (27.8 per cent) and was followed by groups O and T (6.7 and 7.8 per cent, respectively) while in the control group no resorption was observed. Electrical pulp testing revealed the highest prevalence of loss of tooth vitality in group TO (7.3 per cent) in which the highest prevalence of pulp obliteration was also found. It can be concluded that the combination of trauma with orthodontic tipping renders the teeth more susceptible to complications, especially to root resorption and loss of vitality.

"author": [ { "dropping-particle": "", "family": "Brin", "given": "Ilana", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Ben-Bassat", "given": "Yocheved", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Heling", "given": "Ilana", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Engelberg", "given": "Avraham", "non-dropping-particle": "", "parse-names": false, "suffix": "" } ], "container-title": "European Journal of Orthodontics", "id": "ITEM-1", "issue": "5", "issued": { "date-parts": [ [ "1991" ] ] }, "page": "372-377", "title": "The influence of orthodontic treatment on previously traumatized permanent incisors", "type": "article-journal", "volume": "13", "uris": [ "http://www.mendeley.com/documents/?uuiid=08124592-2d9f-48c6-9f49-f78f54c0888e" ] ], "mendeley": { "formattedCitation": "(38)", "plainTextFormattedCitation": "(38)", "previouslyFormattedCitation": "(38)" }, "properties": { "noteIndex": 0 }, "schema": "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } No statistically significant correlation was found ( $P=0.667$ ) between severity of OIIRR at 9 months of treatment and history of trauma to the anterior teeth. This is in agreement with Artun et al. {ADDIN CSL\_CITATION { "citationItems": [ { "id": "ITEM-1", "itemData": { "DOI": "10.1043/0003-3219(2005)75[919:ARRSAM]2.0.CO;2", "ISBN": "1097-6752 (Electronic)\r0889-5406 (Linking)", "ISSN": "0003-3219", "PMID": "16448232", "abstract": "The low explained variance of identified risk factors for apical root resorption in orthodontic patients suggests effects of parameters related to individual predisposition. Our purpose was to explore this hypothesis. We evaluated standardized periapical radiographs of the maxillary incisors made before treatment (T1) as well as at about six and 12 months after bracket placement (T2 and T3) of 247 patients aged 10.1 to 57.1 years at T1. The radiographs were converted to digital images, and commercially available software was used to correct for differences in projection. The results showed that 20.2%, 7.7%, and 5.3% of the patients had > or =1 tooth with >2.0, 3.0, and 4.0 mm resorption at T3, respectively. Pearson's correlation revealed an association between resorption from T1 to T2 and from T2 to T3 ( $P < .01$ ). The risk of > or =1 tooth with >1.0 mm resorption from T2 to T3 was 3.8 times higher (95% CI 2.4-6.0) in patients with > or =1 tooth with >1.0 mm from T1 to T2 than in those without. Also, resorption was more pronounced ( $P < .001$ ) from T2 to T3 in patients with > or =1 tooth with >1.0 mm and >2.0 resorption from T1 to T2 than in those without. The explained variance of identified risk factors was <10%. Orthodontic patients with detectable root resorption during the first six months of active treatment are more likely to experience resorption in the following six-month period than those without." }, "author": [ { "dropping-particle": "", "family": "Artun", "given": "Jon", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Smale", "given": "Isolde", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Behbehani", "given": "Faraj", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Doppel", "given": "Diane", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Van't Hof", "given": "Martin", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Kuijpers-Jagtman", "given": "Anne M", "non-dropping-particle": "", "parse-names": false, "suffix": "" } ], "container-title": "The Angle orthodontist", "id": "ITEM-1", "issue": "6", "issued": { "date-parts": [ [ "2005" ] ] }, "page": "919-26", "title": "Apical root resorption six and 12 months after initiation of fixed orthodontic appliance therapy.", "type": "article-journal", "volume": "75", "uris": [ "http://www.mendeley.com/documents/?uuiid=4e3a45fd-4e55-4c5f-b95c-8cb5ef695394" ] ], "mendeley": { "formattedCitation": "(29)", "plainTextFormattedCitation": "(29)", "previouslyFormattedCitation": "(29)" }, "properties": { "noteIndex": 0 }, "schema": "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } and Smale et al. {ADDIN CSL\_CITATION { "citationItems": [ { "id": "ITEM-1", "itemData": { "DOI":



"10.1016/j.ajodo.2003.12.030", "ISSN" : "0889-5406 (Print)", "PMID" : "16027626", "abstract" : "INTRODUCTION: Individual predisposition might be a major reason for the observed variation in apical orthodontic root resorption. If so, resorption might be expressed during the initial stages of orthodontic therapy in patients at risk. METHODS: To explore this hypothesis, we evaluated standardized, digitized periapical radiographs made before treatment (T1) and at a mean period of 6.4 months (SD 0.9) after placement of maxillary incisor brackets (T2) in 290 patients (age range, 10.1 to 57.1 years at T1). Anamnestic and treatment parameters were recorded according to a protocol, and maxillary incisor irregularity was measured on T1 study models. RESULTS: The mean average root resorption for 4 incisors was 0.53 mm (SD 0.47), whereas the sample mean of the most severely resorbed tooth per patient was 1.18 mm (SD 0.86). A total of 4.1% of the patients had an average resorption of 1.5 mm or more, and 15.5% had at least 1 tooth with 2.0 mm or more resorption. The maximum amount of resorption was 4.4 mm. Multivariate linear regression showed that deviated root form and increased T1-to-T2 time period were risk factors for apical root resorption of the central incisors; normal root form and wide roots were preventive factors, with an explained variance of 14%. Similarly, long roots, narrow roots, and increased T1-to-T2 time period were risk factors for resorption of the lateral incisors, whereas normal root form was a preventive factor, with an explained variance of 24%. Parameters associated with use of rectangular wire, presence of incisor irregularity, and history of trauma were not identified as risk factors. Use of elastics was not included in the regression analyses. CONCLUSIONS: Root resorption can begin in the early leveling stages of orthodontic treatment. About 4.1% of patients studied had an average resorption of 1.5 mm or more of the 4 maxillary incisors, and about 15.5% had 1 or more maxillary incisors with resorption of 2.0 mm or more from 3 to 9 months after initiation of fixed appliance therapy. Although teeth with long, narrow, and deviated roots are at increased risk of resorption during this early stage, the explained variance of these risk factors is less than 25%.", "author" : [ { "dropping-particle" : "", "family" : "Smale", "given" : "Isolde", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Artun", "given" : "Jon", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Behbehani", "given" : "Faraj", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Doppel", "given" : "Diane", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "van't Hof", "given" : "Martin", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Kuijpers-Jagtman", "given" : "Anne M", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics", "id" : "ITEM-1", "issue" : "1", "issued" : { "date-parts" : [ [ "2005" ] ] }, "page" : "57-67", "title" : "Apical root resorption 6 months after initiation of fixed orthodontic appliance therapy.", "type" : "article-journal", "volume" : "128", "uris" : [ "http://www.mendeley.com/documents/?uuiid=39ee6d79-cd35-4b4f-8ecc-464a75ccf518" ] ], "mendeley" : { "formattedCitation" : "(8)", "plainTextFormattedCitation" : "(8)", "previouslyFormattedCitation" : "(8)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } } who found no significant association between history of trauma and the severity of OIHR at 6 and 12 month from the start of treatment. The current results are also in agreement with Weltman et al. {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1016/j.ajodo.2009.06.021", "ISBN" : "1097-6752 (Electronic)", "ISSN" : "0889-5406 (Linking)", "ISSN" : "1097-6752", "PMID" : "20362905", "abstract" : "INTRODUCTION: This systematic review evaluated root resorption as an outcome for patients who had orthodontic tooth movement. The results could provide the best available evidence for clinical decisions to minimize the risks and severity of root resorption. METHODS: Electronic databases were searched, nonelectronic journals were hand searched, and experts in the field were consulted with no language restrictions. Study selection criteria included randomized clinical trials involving human subjects for orthodontic tooth movement, with fixed appliances, and root resorption recorded during or after treatment. Two authors independently reviewed and extracted data from the selected studies on a standardized form. RESULTS: The searches retrieved 921 unique citations. Titles and abstracts identified 144 full articles from which 13 remained after the inclusion criteria were applied. Differences in the methodologic approaches and

reporting results made quantitative statistical comparisons impossible. Evidence suggests that comprehensive orthodontic treatment causes increased incidence and severity of root resorption, and heavy forces might be particularly harmful. Orthodontically induced inflammatory root resorption is unaffected by archwire sequencing, bracket prescription, and self-ligation. Previous trauma and tooth morphology are unlikely causative factors. There is some evidence that a 2 to 3 month pause in treatment decreases total root resorption. CONCLUSIONS: The results were inconclusive in the clinical management of root resorption, but there is evidence to support the use of light forces, especially with incisor intrusion.", "author": [ { "dropping-particle": "", "family": "Weltman", "given": "B", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Vig", "given": "K W", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Fields", "given": "H W", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Shanker", "given": "S", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Kaizar", "given": "E E", "non-dropping-particle": "", "parse-names": false, "suffix": "" } ], "container-title": "American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics", "id": "ITEM-1", "issue": "4", "issued": { "date-parts": [ [ "2010" ] ] }, "page": "462-76; discussion 12A", "title": "Root resorption associated with orthodontic tooth movement: a systematic review", "type": "article-journal", "volume": "137", "uris": [ "http://www.mendeley.com/documents/?uid=74bf74a7-056b-470e-aa38-ec8ac56e767e" ] }, "mendeley": { "formattedCitation": "(25)", "plainTextFormattedCitation": "(25)", "previouslyFormattedCitation": "(25)" }, "properties": { "noteIndex": 0 }, "schema": "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } } who reported that incisors with a history of trauma but no signs of root resorption at the beginning of treatment had the same prevalence of OIIRR as those without trauma.

#### *Correlation between OIIRR and abnormal root morphology:*

In the current study 23.5% of the maxillary central incisors had some form of abnormality in root morphology. This percentage is higher than that reported by Sameshima and Sinclair {ADDIN CSL\_CITATION { "citationItems": [ { "id": "ITEM-1", "itemData": { "DOI": "10.1067/mod.2001.113409", "ISBN": "0889-5406 (Print)|0889-5406 (Linking)", "ISSN": "08895406", "PMID": "11343022", "abstract": "The purpose of this study was to determine whether it would be possible to identify pretreatment factors that will allow the clinician to predict the incidence, location, and severity of root resorption before the commencement of orthodontic treatment. The records of 868 patients who were treated with full, fixed edgewise appliances were obtained from 6 private offices; full-mouth periapical radiographs were used to accurately assess apical root resorption from first molar to first molar in both arches. The results showed that resorption occurs primarily in the maxillary anterior teeth, averaging over 1.4 mm. The worst resorption was seen in maxillary lateral incisors and in teeth with abnormal root shape (pipette, pointed, or dilacerated). Adult patients experienced more resorption than children did in the mandibular anterior segment only. Asian patients were found to experience significantly less root resorption than white or Hispanic patients. Increased overjet, but not overbite, was significantly associated with greater root resorption. There was no difference in either the incidence or severity of root resorption between male and female patients. (Am J Orthod Dentofacial Orthop 2001;119:505-10).", "author": [ { "dropping-particle": "", "family": "Sameshima", "given": "Glenn T.", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Sinclair", "given": "Peter M.", "non-dropping-particle": "", "parse-names": false, "suffix": "" } ], "container-title": "American Journal of Orthodontics and Dentofacial Orthopedics", "id": "ITEM-1", "issue": "5", "issued": { "date-parts": [ [ "2001" ] ] }, "page": "505-510", "title": "Predicting and preventing root resorption: Part I. Diagnostic factors", "type": "article-journal", "volume": "119", "uris": [ "http://www.mendeley.com/documents/?uid=89d9c834-b6a5-4a34-bfbf-0c67bbb9d8c3" ] } ], "mendeley": { "formattedCitation": "(39)", "plainTextFormattedCitation": "(39)", "previouslyFormattedCitation": "(39)" }, "properties": { "noteIndex": 0 }, "schema": "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } } at 2.7% and lower than that reported by Brin et al. {ADDIN CSL\_CITATION { "citationItems": [ { "id": "ITEM-1",

"itemData" : { "DOI" : "10.1016/S0889-5406(03)00166-5", "ISBN" : "0889-5406 (Print)\r0889-5406 (Linking)", "ISSN" : "08895406", "PMID" : "12923510", "abstract" : "External apical root resorption (EARR) is an imperfectly understood problem of orthodontic treatment. The records of 138 children with Class II malocclusion (overjet > 7 mm) participating in a randomized clinical trial of early orthodontic treatment were reviewed. The patients were treated in either 1 phase with fixed appliances only (n = 49) or 2 phases with headgear (n = 49) or bionator (n = 40) followed by fixed appliances. The 3 groups were similar in age, sex, and malocclusion severity at enrollment. The records examined included anamnestic data, clinical examination records, panoramic radiographs before and after fixed appliance therapy, and posttreatment periapical radiographs. All radiographs were reviewed and scored independently by 2 examiners for maxillary incisor root development, morphology, and EARR. Of the 532 incisors scored, 11% of central and 14% of lateral incisors demonstrated moderate to severe (>2 mm) EARR. The proportion of incisors with moderate to severe EARR was slightly greater in the 1-phase treatment group. There was no difference in the incidence of EARR between teeth that had had trauma and those that had not, and there was only a slight increase in frequency of root resorption in teeth with unusual root morphology. Significant associations exist among EARR, the magnitude of overjet reduction, and the time spent wearing fixed appliances. However, not all incisors in a child respond in the same way, so other variables must play a role in determining the root response to orthodontic forces.", "author" : [ { "dropping-particle" : "", "family" : "Brin", "given" : "Ilana", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Tulloch", "given" : "J. F Camilla", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Koroluk", "given" : "Lorne", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Philips", "given" : "Ceib", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "American Journal of Orthodontics and Dentofacial Orthopedics", "id" : "ITEM-1", "issue" : "2", "issued" : { "date-parts" : [ [ "2003" ] ] }, "page" : "151-156", "title" : "External apical root resorption in Class II malocclusion: A retrospective review of 1- versus 2-phase treatment", "type" : "article", "volume" : "124" }, "uris" : [ "http://www.mendeley.com/documents/?uid=9a13cf50-118a-4291-afac-50c5c86185f7" ] }, "mendeley" : { "formattedCitation" : "(40)", "plainTextFormattedCitation" : "(40)", "previouslyFormattedCitation" : "(40)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } } and Marques et al. {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1016/j.jodo.2008.04.024", "ISBN" : "1097-6752 (Electronic)\r0889-5406 (Linking)", "ISSN" : "08895406", "PMID" : "20197177", "abstract" : "Introduction: Our aims in this study were to assess the prevalence of severe root resorption and identify possible associations in orthodontic patients treated with the edgewise method. Methods: The sample included 1049 patients who had periapical radiographs taken for all incisors before and after treatment. The radiographs were examined by 2 orthodontists using an x-ray viewer with standard light intensity. These variables were collected: root shape, overbite, initial resorption, and hypodontia. The patients were classified according to sex, Angle classification, ethnicity, age, duration of treatment, type of dentition (mixed or permanent), and treatment with or without extraction of 4 premolars. Resorption was considered severe when it affected more than a third of the length of the root. Statistical analysis included the chi-square test and both simple and multiple logistic regression (P \u22640.05). Results: Severe root resorption was observed in 14.5% of the sample. Patients treated with exodontia of the first premolars (odds ratio [95% CI] = 6.38 [4.2-9.7]), those who had triangle-shaped roots at the beginning of treatment (odds ratio [95% CI] = 4.67 [3.1-6.9]), and those with initial root resorption (odds ratio [95% CI] = 4.52 [2.7-7.6]) had a greater chance of developing severe root resorption during orthodontic treatment. Conclusions: A high prevalence of severe root resorption was observed in Brazilian patients treated with the edgewise method. The main factors directly involved in severe resorption were extraction of first premolars, triangle-shaped roots, and root resorption before treatment. \u00a9 2010 American Association of Orthodontists.", "author" : [ { "dropping-particle" : "", "family" : "Marques", "given" : "Leandro Silva", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Ramos-Jorge", "given" : "Maria Let\u00e9cia", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Rey", "given" : "Ana Cristina", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Armond", "given" : "M\u00f4nica Costa", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ] }

: false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Oliveira Ruellas", "given" : "Ant\u00f4nio Carlos", "non-dropping-particle" : "de", "parse-names" : false, "suffix" : "" } ], "container-title" : "American Journal of Orthodontics and Dentofacial Orthopedics", "id" : "ITEM-1", "issue" : "3", "issued" : { "date-parts" : [ [ "2010" ] ] }, "page" : "384-388", "title" : "Severe root resorption in orthodontic patients treated with the edgewise method: Prevalence and predictive factors", "type" : "article-journal", "volume" : "137" }, "uris" : [ "http://www.mendeley.com/documents/?uuiid=54733d92-1c0b-4a2e-9ca7-f3ba78163145" ] } ], "mendeley" : { "formattedCitation" : "(41)", "plainTextFormattedCitation" : "(41)", "previouslyFormattedCitation" : "(41)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } } (35.5% and 31.5% respectively). This variation in the prevalence of abnormal root morphology among studies can be explained by the different criteria used in the subjective scoring indices for root morphology in each study. No statistically significant ( $P=0.115$ ) correlation was found in the current study between the teeth with abnormal root morphology and the severity of OIRR at 9 months. The results from the current study did not agree with findings of the systematic review by Weltman et al. {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1016/j.ajodo.2009.06.021", "ISBN" : "1097-6752 (Electronic)\r0889-5406 (Linking)", "ISSN" : "1097-6752", "PMID" : "20362905", "abstract" : "INTRODUCTION: This systematic review evaluated root resorption as an outcome for patients who had orthodontic tooth movement. The results could provide the best available evidence for clinical decisions to minimize the risks and severity of root resorption. METHODS: Electronic databases were searched, nonelectronic journals were hand searched, and experts in the field were consulted with no language restrictions. Study selection criteria included randomized clinical trials involving human subjects for orthodontic tooth movement, with fixed appliances, and root resorption recorded during or after treatment. Two authors independently reviewed and extracted data from the selected studies on a standardized form. RESULTS: The searches retrieved 921 unique citations. Titles and abstracts identified 144 full articles from which 13 remained after the inclusion criteria were applied. Differences in the methodologic approaches and reporting results made quantitative statistical comparisons impossible. Evidence suggests that comprehensive orthodontic treatment causes increased incidence and severity of root resorption, and heavy forces might be particularly harmful. Orthodontically induced inflammatory root resorption is unaffected by archwire sequencing, bracket prescription, and self-ligation. Previous trauma and tooth morphology are unlikely causative factors. There is some evidence that a 2 to 3 month pause in treatment decreases total root resorption. CONCLUSIONS: The results were inconclusive in the clinical management of root resorption, but there is evidence to support the use of light forces, especially with incisor intrusion.", "author" : [ { "dropping-particle" : "", "family" : "Weltman", "given" : "B", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Vig", "given" : "K W", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Fields", "given" : "H W", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Shanker", "given" : "S", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Kaizar", "given" : "E E", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics", "id" : "ITEM-1", "issue" : "4", "issued" : { "date-parts" : [ [ "2010" ] ] }, "page" : "462-76; discussion 12A", "title" : "Root resorption associated with orthodontic tooth movement: a systematic review", "type" : "article-journal", "volume" : "137" }, "uris" : [ "http://www.mendeley.com/documents/?uuiid=74bf74a7-056b-470e-aa38-ec8ac56e767e" ] } ], "mendeley" : { "formattedCitation" : "(25)", "plainTextFormattedCitation" : "(25)", "previouslyFormattedCitation" : "(25)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } } who reported that there is evidence that abnormal roots may be at slightly higher risk of moderate to severe risk for OIRR when compared to normal roots. However, Weltman et al. {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1016/j.ajodo.2009.06.021", "ISBN" : "1097-6752 (Electronic)\r0889-5406 (Linking)", "ISSN" : "1097-6752", "PMID" : "20362905", "abstract" : "INTRODUCTION: This systematic review evaluated root resorption as an outcome for

patients who had orthodontic tooth movement. The results could provide the best available evidence for clinical decisions to minimize the risks and severity of root resorption. METHODS: Electronic databases were searched, nonelectronic journals were hand searched, and experts in the field were consulted with no language restrictions. Study selection criteria included randomized clinical trials involving human subjects for orthodontic tooth movement, with fixed appliances, and root resorption recorded during or after treatment. Two authors independently reviewed and extracted data from the selected studies on a standardized form. RESULTS: The searches retrieved 921 unique citations. Titles and abstracts identified 144 full articles from which 13 remained after the inclusion criteria were applied. Differences in the methodologic approaches and reporting results made quantitative statistical comparisons impossible. Evidence suggests that comprehensive orthodontic treatment causes increased incidence and severity of root resorption, and heavy forces might be particularly harmful. Orthodontically induced inflammatory root resorption is unaffected by archwire sequencing, bracket prescription, and self-ligation. Previous trauma and tooth morphology are unlikely causative factors. There is some evidence that a 2 to 3 month pause in treatment decreases total root resorption. CONCLUSIONS: The results were inconclusive in the clinical management of root resorption, but there is evidence to support the use of light forces, especially with incisor intrusion.

author : [ { "dropping-particle" : "", "family" : "Weltman", "given" : "B", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Vig", "given" : "K W", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Fields", "given" : "H W", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Shanker", "given" : "S", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Kaizar", "given" : "E E", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics", "id" : "ITEM-1", "issue" : "4", "issued" : { "date-parts" : [ [ "2010" ] ] }, "page" : "462-76; discussion 12A", "title" : "Root resorption associated with orthodontic tooth movement: a systematic review", "type" : "article-journal", "volume" : "137" }, "uris" : [ "http://www.mendeley.com/documents/?uid=74bf74a7-056b-470e-aa38-ec8ac56e767e" ] } ], "mendeley" : { "formattedCitation" : "(25)", "plainTextFormattedCitation" : "(25)", "previouslyFormattedCitation" : "(25)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } } based their finding on the results from a single randomized clinical trial {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1016/S0889-5406(03)00166-5", "ISBN" : "0889-5406 (Print)\r0889-5406 (Linking)", "ISSN" : "08895406", "PMID" : "12923510", "abstract" : "External apical root resorption (EARR) is an imperfectly understood problem of orthodontic treatment. The records of 138 children with Class II malocclusion (overjet > 7 mm) participating in a randomized clinical trial of early orthodontic treatment were reviewed. The patients were treated in either 1 phase with fixed appliances only (n = 49) or 2 phases with headgear (n = 49) or bionator (n = 40) followed by fixed appliances. The 3 groups were similar in age, sex, and malocclusion severity at enrollment. The records examined included anamnestic data, clinical examination records, panoramic radiographs before and after fixed appliance therapy, and posttreatment periapical radiographs. All radiographs were reviewed and scored independently by 2 examiners for maxillary incisor root development, morphology, and EARR. Of the 532 incisors scored, 11% of central and 14% of lateral incisors demonstrated moderate to severe (>2 mm) EARR. The proportion of incisors with moderate to severe EARR was slightly greater in the 1-phase treatment group. There was no difference in the incidence of EARR between teeth that had had trauma and those that had not, and there was only a slight increase in frequency of root resorption in teeth with unusual root morphology. Significant associations exist among EARR, the magnitude of overjet reduction, and the time spent wearing fixed appliances. However, not all incisors in a child respond in the same way, so other variables must play a role in determining the root response to orthodontic forces." }, "author" : [ { "dropping-particle" : "", "family" : "Brin", "given" : "Ilana", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Tulloch", "given" : "J. F Camilla", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Koroluk", "given" : "Lorne", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Philips", "given" : "Ceib",

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#### *Correlation between OIIRR and duration of rectangular NiTi archwires:*

In the current study the periapical radiographs were taken after 9 months from the start of orthodontic treatment which corresponded with the end of the alignment stage. The use of rectangular NiTi archwires during the alignment stage introduces third order movement (root torque). Previous studies have implicated rectangular archwires and torque expression for increased severity OIIRR {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "ISBN" : "0141-5387 (Print)\r0141-5387 (Linking)", "ISSN" : "0141-5387", "PMID" : "9753824", "abstract" : "The aim of this study was to evaluate the risk of root resorption during orthodontic treatment of patients with aplasia, and to analyse the relative importance of some anamnestic and treatment variables. The subjects comprised 68 orthodontically treated patients with 1-16 congenitally missing teeth. The age of the patients was 11-20 years (mean 15 years). All patients were treated with fixed edgewise appliances. The purpose of the orthodontic treatment varied: to create optimal conditions for prosthetic restorations or osseointegrated implants, or to achieve aesthetic and functional alignment of teeth in less severe cases. The degree of root resorption was assessed before and after treatment from intra-oral radiographs of the maxillary incisors using a scale of 0-4. In all, 186 maxillary incisors were evaluated. The degree of apical root resorption was significantly greater in cases of multiple aplasia (4-16 missing teeth) than in those with only one to three missing teeth. Root form, treatment time with rectangular wires and intermaxillary elastics, and total treatment time were significantly related to root resorption. Discriminant analysis disclosed that the following variables were the most important determinants of root resorption: number of missing teeth, root form, and time with rectangular archwires and intermaxillary elastics. It is concluded that there is a high risk of apical root resorption during orthodontic treatment in patients with multiple aplasia (four or more teeth), in particular in teeth with an abnormal root form and lengthy treatment with elastics and rectangular archwires.", "author" : [ { "dropping-particle" : "", "family" : "Levander", "given" : "E", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Malmgren", "given" : "O", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Stenback", "given" : "K", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ] }, "container-title" : "European journal of orthodontics", "id" : "ITEM-1", "issued" : { "date-parts" : [ [ "1998" ] ] }, "page" : "427-434", "title" : "Apical root resorption during orthodontic treatment of patients with multiple aplasia: a study of maxillary incisors.", "type" : "article-journal", "volume" : "20" }, "uris" : [ "http://www.mendeley.com/documents/?uuid=22cf4910-56ba-477b-8d49-1a08b216c991" ] } ], "mendeley" : { "formattedCitation" : "(37)", "plainTextFormattedCitation" : "(37)", "previouslyFormattedCitation" : "(37)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } }. However, in the current study the rectangular NiTi archwires were used for more than half the duration (52-57%) of the alignment stage and no statistically significant correlation was found between the severity of OIIRR and the duration of rectangular NiTi archwire use. It is important to note that this is not a representation of the full duration of treatment which requires stainless steel rectangular archwires. This is in agreement with Mandall et al. {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1093/ejo/cj1030", "ISBN" : "0141-5387 (Print)\r0141-5387 (Linking)", "ISSN" : "01415387", "PMID" : "17041083", "abstract" : "The aim of this study was to compare three orthodontic archwire sequences. One hundred and fifty-four 10- to 17-year-old patients were treated in three centres and randomly allocated to one of three groups: A = 0.016-inch nickel titanium (NiTi), 0.018 x 0.025-inch NiTi, and 0.019 x 0.025-inch stainless steel (SS); B = 0.016-inch

NiTi, 0.016-inch SS, 0.020-inch SS, and 0.019 x 0.025-inch SS; and C = 0.016 x 0.022-inch copper (Cu) NiTi, 0.019 x 0.025-inch CuNiTi, and 0.019 x 0.025-inch SS. At each archwire change and for each arch, the patients completed discomfort scores on a seven-point Likert scale at 4 hours, 24 hours, 3 days, and 1 week. Time in days and the number of visits taken to reach a 0.019 x 0.025-inch SS working archwires were calculated. A periapical radiograph of the upper left central incisor was taken at the start of the treatment and after placement of the 0.019 x 0.025-inch SS wire so root resorption could be assessed. There were no statistically significant differences between archwire sequences A, B, or C for patient discomfort ( $P > 0.05$ ) or root resorption ( $P = 0.58$ ). The number of visits required to reach the working archwire was greater for sequence B than for A ( $P = 0.012$ ) but this could not be explained by the increased number of archwires used in sequence B.", "author" : [ { "dropping-particle" : "", "family" : "Mandall", "given" : "N. A.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Lowe", "given" : "C.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "V.", "family" : "Worthington", "given" : "H.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Sandler", "given" : "J.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Derwent", "given" : "S.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Abdi-Oskouei", "given" : "M.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Ward", "given" : "S.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "European Journal of Orthodontics", "id" : "ITEM-1", "issue" : "6", "issued" : { "date-parts" : [ [ "2006" ] ] }, "page" : "561-566", "title" : "Which orthodontic archwire sequence? A randomized clinical trial", "type" : "article-journal", "volume" : "28" }, "uris" : [ [ "http://www.mendeley.com/documents/?uuid=272f992b-ee04-42a6-a000-1c55e86f7613" ] ] }, "mendeley" : { "formattedCitation" : "(27)", "plainTextFormattedCitation" : "(27)", "previouslyFormattedCitation" : "(27)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } } who reported no statistically significant difference in the severity of OIIRR when comparing different archwire sequences where one group had used rectangular archwires from day one for the alignment stage.

#### *Patient perception of pain during orthodontic treatment*

In the current study most of the study participants experienced soreness related to teeth, mouth, and rubbing. However, the majority of those participants rated this teeth soreness as “a little”. It was noted that 10.6 % of the participants reported “a lot of sore teeth” and 11.2% reported “no sore teeth” while the majority 78.2% of the sample reported little sore teeth at 6 months. This finding is in agreement with most studies that have investigated patient perception of wearing different types of orthodontic appliances {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1093/ejo/cjl030", "ISBN" : "0141-5387 (Print)\r0141-5387 (Linking)", "ISSN" : "01415387", "PMID" : "17041083", "abstract" : "The aim of this study was to compare three orthodontic archwire sequences. One hundred and fifty-four 10- to 17-year-old patients were treated in three centres and randomly allocated to one of three groups: A = 0.016-inch nickel titanium (NiTi), 0.018 x 0.025-inch NiTi, and 0.019 x 0.025-inch stainless steel (SS); B = 0.016-inch NiTi, 0.016-inch SS, 0.020-inch SS, and 0.019 x 0.025-inch SS; and C = 0.016 x 0.022-inch copper (Cu) NiTi, 0.019 x 0.025-inch CuNiTi, and 0.019 x 0.025-inch SS. At each archwire change and for each arch, the patients completed discomfort scores on a seven-point Likert scale at 4 hours, 24 hours, 3 days, and 1 week. Time in days and the number of visits taken to reach a 0.019 x 0.025-inch SS working archwires were calculated. A periapical radiograph of the upper left central incisor was taken at the start of the treatment and after placement of the 0.019 x 0.025-inch SS wire so root resorption could be assessed. There were no statistically significant differences between archwire sequences A, B, or C for patient discomfort ( $P > 0.05$ ) or root resorption ( $P = 0.58$ ). The number of visits required to reach the working archwire was greater for sequence B than for A ( $P = 0.012$ ) but this could not be explained by the increased number of archwires used in sequence B.", "author" : [ { "dropping-particle" : "", "family" : "Mandall", "given" : "N. A.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Lowe", "given" : "C.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "V.", "family" :

"Worthington", "given" : "H.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Sandler", "given" : "J.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Derwent", "given" : "S.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Abdi-Oskouei", "given" : "M.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Ward", "given" : "S.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "European Journal of Orthodontics", "id" : "ITEM-1", "issue" : "6", "issued" : { "date-parts" : [ [ "2006" ] ] }, "page" : "561-566", "title" : "Which orthodontic archwire sequence? A randomized clinical trial", "type" : "article-journal", "volume" : "28" }, "uris" : [ "http://www.mendeley.com/documents/?uid=272f992b-ee04-42a6-a000-1c55e86f7613" ] ], { "id" : "ITEM-2", "itemData" : { "DOI" : "10.1093/ejo/cjm131", "ISBN" : "1460-2210 (Electronic)\r0141-5387 (Linking)", "ISSN" : "01415387", "PMID" : "18339656", "abstract" : "The aim of this study was to compare the degree of discomfort experienced during the period of initial orthodontic tooth movement using Damon3 self-ligating and Synthesis conventional ligating pre-adjusted bracket systems. Sixty-two subjects were recruited from two centres (32 males and 30 females; mean age 16 years, 3 months) with lower incisor irregularity between 5 and 12 mm and a prescribed extraction pattern, including lower first premolar teeth. These subjects were randomly allocated for treatment with either bracket system. Fully ligated Damon3 0.014-inch Cu NiTi archwires were used for initial alignment in both groups. Following archwire insertion, the subjects were given a prepared discomfort diary to complete over the first week, recording discomfort by means of a 100 mm visual analogue scale at 4 hours, 24 hours, 3 days, and 1 week. The subjects also noted any self-prescribed analgesics that were taken during the period of observation. Data were analysed using repeated measures analysis of variance. There were no statistically significant differences in perceived discomfort levels between the two appliances; discomfort did not differ at the first time point and did not develop differently across subsequent measurement times. Overall, this investigation found no evidence to suggest that Damon3 self-ligating brackets are associated with less discomfort than conventional pre-adjusted brackets during initial tooth alignment, regardless of age or gender.", "author" : [ { "dropping-particle" : "", "family" : "Scott", "given" : "Paul", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Sherriff", "given" : "Martyn", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "DiBiase", "given" : "Andrew T.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Cobourne", "given" : "Martyn T.", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "European Journal of Orthodontics", "id" : "ITEM-2", "issue" : "3", "issued" : { "date-parts" : [ [ "2008" ] ] }, "page" : "227-232", "title" : "Perception of discomfort during initial orthodontic tooth alignment using a self-ligating or conventional bracket system: A randomized clinical trial", "type" : "article-journal", "volume" : "30" }, "uris" : [ "http://www.mendeley.com/documents/?uid=044f82b9-e8b8-4fac-b6a3-b6a467d5cb12" ] ] ], "mendeley" : { "formattedCitation" : "(27,42)", "plainTextFormattedCitation" : "(27,42)", "previouslyFormattedCitation" : "(27,42)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } }. Most of the studies in the literature which have assessed pain/discomfort during orthodontic treatment evaluated the first hours, days or weeks of treatment {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1093/ejo/cjm131", "ISBN" : "1460-2210 (Electronic)\r0141-5387 (Linking)", "ISSN" : "01415387", "PMID" : "18339656", "abstract" : "The aim of this study was to compare the degree of discomfort experienced during the period of initial orthodontic tooth movement using Damon3 self-ligating and Synthesis conventional ligating pre-adjusted bracket systems. Sixty-two subjects were recruited from two centres (32 males and 30 females; mean age 16 years, 3 months) with lower incisor irregularity between 5 and 12 mm and a prescribed extraction pattern, including lower first premolar teeth. These subjects were randomly allocated for treatment with either bracket system. Fully ligated Damon3 0.014-inch Cu NiTi archwires were used for initial alignment in both groups. Following archwire insertion, the subjects were given a prepared discomfort diary to complete over the first week, recording discomfort by means of a 100 mm visual analogue scale at 4 hours, 24 hours, 3 days, and 1 week. The subjects also noted any self-prescribed analgesics that were taken during the period of observation. Data were analysed using repeated measures analysis of variance. There were no statistically significant differences in perceived



discomfort levels between the two appliances; discomfort did not differ at the first time point and did not develop differently across subsequent measurement times. Overall, this investigation found no evidence to suggest that Damon3 self-ligating brackets are associated with less discomfort than conventional pre-adjusted brackets during initial tooth alignment, regardless of age or gender.

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This was a prospective, randomized, controlled, clinical trial at the Royal London Hospital, School of Dentistry, in London and the Kent and Canterbury Hospital in Canterbury, United Kingdom. Methods: Sixty- six consecutive patients satisfying the inclusion criteria were enrolled and randomly allocated to treatment with a self-ligating bracket system (SmartClip, 3M Unitek, Monrovia, Calif) and conventional preadjusted edgewise brackets (Victory, 3M Unitek). Initial study models and cephalograms were obtained within a month of starting the trial. All subjects received treatment with the following archwire sequence: 0.016-in round, 0.017 ?? 0.025-in rectangular, 0.019 ?? 0.025-in rectangular martensitic active nickel-titanium archwires, and 0.019 ?? 0.025-in stainless steel archwires. Final records, including study models and a lateral cephalogram, were collected a minimum of 30 weeks after initial appliance placement. Lateral cephalograms were assessed for treatment-related changes in mandibular incisor inclination and position. Transverse dimensional changes in intercanine, interpremolar, and intermolar dimensions, and the amount of crowding alleviated during the study period were assessed by comparison of pretreatment and posttreatment models. All measurements were made with a digital caliper (150 mm ISO 9001 electronic caliper, Tesa Technology, Renens, Switzerland). Results: Sixty patients completed the study. After adjustment for pretreatment values, duration of treatment, and amount of crowding alleviated during the study period, bracket type had little effect on incisor inclination (P = 0.437) and positional changes (P = 0.35), and intercanine (P = 0.967), inter-first premolar (P = 0.495), and inter-second premolar (P = 0.905) dimensions. However, the self-ligating appliance produced slightly more expansion in the molar region, a difference that was statistically significant (P = 0.009). Pretreatment values for incisor inclination (P = 0.044) and transverse dimensions (P = 0.000) affected inclination and transverse changes, respectively, with proclination less likely when the labial segment was proclined at the outset and expansion unlikely during leveling and alignment in wider arches. Greater alleviation of crowding during the study period was observed in patients with greater initial crowding. Conclusion: Self-ligating appliances may be associated with slightly more expansion in the molar region, but otherwise, the two appliance types performed similarly in terms of incisor inclination, intercanine, interpremolar, and intermolar dimensions, and the amount of crowding alleviated during the study period." }, "author": [ { "dropping-particle": "", "family": "Fleming", "given": "Padhraig S.", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "DiBiase", "given": "Andrew T.", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Sarri", "given": "Grammati", "non-dropping-particle": "", "parse-names": false, "suffix": "" }, { "dropping-particle": "", "family": "Lee", "given": "Robert T.", "non-dropping-particle": "", "parse-names": false, "suffix": "" } ], "container-title": "American Journal of Orthodontics and Dentofacial Orthopedics", "id": "ITEM-2", "issue": "3", "issued": { "date-parts": [ [ "2009" ] ] }, "page": "340-347", "title": "Comparison of mandibular arch changes during alignment and leveling with 2 preadjusted edgewise appliances", "type": "article-journal", "volume": "136", "uris": [ "http://www.mendeley.com/documents/?uuiid=26d845f8-5164-403b-9efa-b5436fa97563" ] } ], "mendeley": { "formattedCitation": "(4,42)", "plainTextFormattedCitation": "(4,42)", "previouslyFormattedCitation": "(4,42)" }, "properties": { "noteIndex": 0 }, "schema": "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" }}. 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According to histological studies, OIIRR occurs during the elimination of the hyaline zone which occurs due to reduced blood flow and ischemia after applying orthodontic forces {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1043/0003-3219(2002)072<0180:OIIRRP>2.0.CO;2", "ISBN" : "0003-3219 (Print)\n0003-3219 (Linking)", "ISSN" : "00033219", "PMID" : "11999942", "abstract" : "Over the past 10 years, orthodontically induced inflammatory root resorption (OIIRR) has been increasingly recognized as an iatrogenic consequence of orthodontic treatment. With this in mind, orthodontists should take all known measures to reduce the occurrence of OIIRR. The evidence that we present in this review suggests several procedures known today that can avert this phenomenon; however, none of them can be relied on to completely prevent OIIRR. We believe that future studies might clarify the exact cause and course of OIIRR and, hopefully, help eliminate it. In Part I, we discussed the basic sciences aspects of OIIRR; in Part II, we present the clinical aspects of this phenomenon.", "author" : [ { "dropping-particle" : "", "family" : "Brezniak", "given" : "Naphtali", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Wasserstein", "given" : "Atalia", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "Angle Orthodontist", "id" : "ITEM-1", "issue" : "2", "issued" : { "date-parts" : [ [ "2002" ] ] }, "page" : "180-184", "title" : "Orthodontically Induced Inflammatory Root Resorption. Part II: The Clinical Aspects", "type" : "article", "volume" : "72" }, "uris" : [ [ "http://www.mendeley.com/documents/?uuiid=89b4e744-87dd-4a10-92e2-6aa57ae7c6e3" ] ] }, { "id" : "ITEM-2", "itemData" : { "DOI" : "10.1043/0003-3219(2002)072<0175:OIIRRP>2.0.CO;2", "ISBN" : "0003-3219 (Print)\n0003-3219 (Linking)", "ISSN" : "00033219", "PMID" : "11999941", "abstract" : "Orthodontically induced inflammatory root resorption (OIIRR) or, as it is better known, root resorption, is an unavoidable pathologic consequence of orthodontic tooth movement. It is a certain adverse effect of an otherwise predictable force application. Although it is rarely serious, it is a devastating event when it is radiographically recognized. Orthodontics is probably the only dental specialty that actually uses the inflammatory process as a means of solving functional and esthetic problems. Force application initiates a sequential cellular process. We know exactly how and when it is evoked, but we are unable to predict its actual overall outcome. The extent of this inflammatory process depends on many factors such as the virulence or aggressiveness of the different resorbing cells, as well as the vulnerability and sensitivity of the tissues involved. Individual variation and susceptibility, which are related to this process, remain beyond our understanding. We are therefore unable to predict the incidence and extent of OIIRR after force application. This contemporary review is divided into two parts. In Part I, we discuss the basic sciences aspects of OIIRR as a continuation of our previously published work. In Part II, we present the clinical aspects of this subject.", "author" : [ { "dropping-particle" : "", "family" : "Brezniak", "given" : "Naphtali", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" }, { "dropping-particle" : "", "family" : "Wasserstein", "given" : "Atalia", "non-dropping-particle" : "", "parse-names" : false, "suffix" : "" } ], "container-title" : "Angle Orthodontist", "id" : "ITEM-2", "issue" : "2", "issued" : { "date-parts" : [ [ "2002" ] ] }, "page" : "175-179", "title" : "Orthodontically Induced Inflammatory Root Resorption. Part I: The Basic Science Aspects", "type" : "article", "volume" : "72" }, "uris" : [ [ "http://www.mendeley.com/documents/?uuiid=04438f02-4934-46c8-ace1-c064ea53e0ac" ] ] }, "mendeley" : { "formattedCitation" : "(13,43)", "plainTextFormattedCitation" : "(13,43)", "previouslyFormattedCitation" : "(13,43)" }, "properties" : { "noteIndex" : 0 }, "schema" : "https://github.com/citation-style-language/schema/raw/master/csl-citation.json" } }.

Interestingly, pain during orthodontic tooth movement is thought to occur due to localised ischemia resulting from the orthodontic forces applied during tooth movement {ADDIN CSL\_CITATION { "citationItems" : [ { "id" : "ITEM-1", "itemData" : { "DOI" : "10.1093/ejo/cj1081", "ISBN" : "0141-5387 (Print)\r0141-5387 (Linking)", "ISSN" : "01415387", "PMID" : "17488999", "abstract" : "Orthodontic pain, the most cited negative effect arising from orthodontic force application, is a major concern for parents, patients, and clinicians. Studies have reported this reaction to be a major deterrent to orthodontic treatment and an important reason for discontinuing treatment. Surprisingly this area, which requires attention in clinical practice as well as

in research, is ignored as evidenced by the scarcity of publications on the topic in comparison with other areas of orthodontic research. This review attempts to organize the existing published literature regarding pain, which appears as part of orthodontic mechanotherapy and to address questions that might arise in a clinical setting from the viewpoint of clinicians and patients/parents. It also provides an overview of current management strategies employed for alleviating orthodontic pain.

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### **Limitations**

The data for OIIRR available from the current study is only for the initial stage of treatment (9 months). However, there is enough evidence in the literature to support the significant correlation between the severity of OIIRR at 6-12 months from start of treatment and the severity of OIIRR at the end of treatment. In addition, there are some limitations in using 2 dimensional radiographs in assessing OIIRR. However, 3D CBCT technology was not used in this study due to the relatively high radiation exposure for participants.

### **Generalisability**

The external validity of the study was high as all eligible participants were recruited from a complete cohort presenting for state-funded orthodontic treatment in hospitals in the same health board area. However, the current study was undertaken in a teaching hospital environment which might be different from orthodontic practice in primary care as the cohort included patients with all malocclusion types and both extraction and non-extraction cases.

### ***Opportunities for Future Clinical Research***

Given that there was no statistically, nor clinically significant difference in the current study outcomes between the two study groups, this means the choice of bracket slot size remains the clinician's preference. It would therefore be appropriate to investigate clinician perception and experience of both bracket slot systems for dual arch orthodontic treatment.

### **CONCLUSIONS**

The findings from the current study suggest that the effect of bracket slot size on the severity of OIIRR and patient perception of pain during treatment is not significant.

### **REFERENCES**

**{ADDIN Mendeley Bibliography CSL\_BIBLIOGRAPHY }**

**Figure captions**

- Figure 1a: Periapical radiographs taken at the start of treatment showing an absence of OIRR (Grade 0). The root morphology was normal for both maxillary central incisors at the start of treatment (Score 0).
- Figure 1b: Periapical radiographs taken at nine months of treatment showing extreme OIRR (Grade 4) affecting the maxillary right central incisor and severe OIRR (Grade 3) affecting the maxillary left central incisor.
- Figure 2: CONSORT flowchart describing the flow of participants through each stage of the trial
- Figure 3: Bar chart showing the percentage distribution of OIIRR severity score in the 0.018 and 0.022 study groups
- Figure 4: Bar chart showing the percentage distribution of patient perception of pain /discomfort according to severity of OIIRR score for the whole study sample

**Table captions**

- Table 1 Baseline characteristics of participants in each study group
- Table 2 Distribution of pre- and post- treatment OIIRR and comparison between 0.018 and 0.022 study groups
- Table 3 Descriptive data for root morphology and correlation with severity of OIIRR
- Table 4 Descriptive data for pain experience during treatment and correlation with OIIRR severity

