Supplementary Table 1. Detailed description of the search performed in various databases.

Database	Search strategy	Limits, Results, Inclusion
Pubmed (https://www.ncbi.nlm.nih.gov/pubmed)	(superimpos* AND (digital model*) AND orthodont*) OR (superimpos* AND (digital model*) AND dent*) OR (digital [Title/Abstract] AND superimposition [Title/Abstract] AND orthodont*) OR (digital [Title/Abstract] AND superimposition [Title/Abstract] AND dent*) OR (superimpos* AND ruga*) OR (regist* AND (digital model*) AND orthodont*) OR (regist* AND (digital model*) AND dent*) OR (digital [Title/Abstract] AND superimposition [Title/Abstract] AND orthodont*) OR (digital [Title/Abstract] AND superimposition [Title/Abstract] AND dent*) OR (regist* AND ruga*)	Limits: - Publication date: From 0001/01/01 to “current” Search Builder: ‘All Fields’ Results: 215
EMBASE (www.embase.com)	(superimpos* AND (digital model*) AND orthodont*) OR (superimpos* AND (digital model*) AND dent*) OR (digital AND superimposition AND orthodont*) OR (digital AND superimposition AND dent*) OR (superimpos* AND ruga*) OR (regist* AND (digital model*) AND orthodont*) OR (regist* AND (digital model*) AND dent*) OR (digital AND superimposition AND orthodont*) OR (digital AND superimposition AND dent*) OR (regist* AND ruga*)	Limits: - Publication date: From 0001/01/01 to current Search Builder: ‘All Fields’ Special function used: non Results: 187
Google Scholar (www.scholar.google.com)	**Advanced search 1** With the exact phrase: 3D superimposition With at least one of the words: “dental cast” OR “stone model” OR “dental model” **Advanced search 2** With the exact phrase: 3D registration With at least one of the words: “dental cast” OR “stone model” OR “dental model”	Limits: - Publication date: From 0001/01/01 to “current” Search Builder: ‘All Fields’ Results: 100
Cochrane Reviews (Reviews and Protocols), Other Reviews, Trials and Methods Studies search (www.thecochranelibrary.com)	(superimpos* AND (digital model*) AND orthodont*) OR (superimpos* AND (digital model*) AND dent*) OR (digital AND superimposition AND orthodont*) OR (digital AND superimposition AND dent*) OR (superimpos* AND ruga*) OR (regist* AND (digital model*) AND orthodont*) OR (regist* AND (digital model*) AND dent*) OR (digital AND superimposition AND orthodont*) OR (digital AND superimposition AND dent*) OR (regist* AND ruga*)	Limits: - Publication date: from 0001/01/01 to “current” Search Builder: ‘All Fields’ Special function used: “Word variations have been searched” Results: 36
Gray literature- OpenGrey http://www.opengrey.eu/	3D superimposition, 3-D superimposition, 3 Dimensional superimposition, 3-Dimensional superimposition, three-dimensional superimposition, 3D registration, 3-D registration, 3 Dimensional registration, 3-Dimensional registration, three-dimensional registration	Results: 152
Gray literature- Grey Literature Report www.greylit.org	3D superimposition, 3-D superimposition, 3 Dimensional superimposition, 3-Dimensional superimposition, three-dimensional superimposition, 3D registration, 3-D registration, 3 Dimensional registration, 3-Dimensional registration, three-dimensional registration	Results: 0

Supplementary Table 2. Quality assessment of the included studies through the QUADAS-2 tool.

Risk of Bias						Applicability Concerns			
Study name	**Patient Selection**	**Index Test**	**Reference Standard**	**Flow & Timing**	**Total risk of bias**	**Patient Selection**	**Index Test**	**Reference Standard**	**Total Applicability concerns**
An et al J Orofac Orthop (2015) (3)	☺	☺	☹ (Execution: different reference used; Cephalograms used as reference standard; blinding not reported)	☺	☹	☺	☹ (Execution: different reference used)	☹ (Execution: different reference used)	☹
Becker et al J Orofac Orthop (2018) (6)	☺	☹ (Only mean values, no method error)	☹ (Only mean values, no method error)	☺	☹	☹ (Large age range)	☹ (Only mean values, no method error)	☹ (Only mean values, no method error)	☹
Cha et al Eur J Orthod (2007) (10)	☺	☹ (Interpretation: only mean values were tested)	? (Cephalograms used as reference standard; blinding not reported)	☺	☹	☹ (Growing and non-growing patients included)	☹ (Execution: exclusion of the z-axis measurements; no method error; only mean values were tested)	☺	☹
Chen et al Orthod Craniofac Res (2011) (11)	☺	☹ (Interpretation: only mean values were tested)	☹ (Conduction: the way mini screw position was evaluated)	☺	☹	☺	☹ (Interpretation: only mean values were tested)	☺	☹
Choi et al Angle Orthod (2010) (12)	☺	☹ (Execution: the palate wasn't changed in the simulated treatment)	☺	☺	☹	☹ (Age info not available; sample not appropriate)	☹ (Execution: the palate wasn't changed in the simulated treatment)	? (Execution: identical tooth models)	☹
Choi et al Korean J Orthod (2012) (13)	☺	☺	? (Cephalograms used as reference standard; blinding not reported)	☺	?	☺	☺	☺	☺
Ganzer et al Eur J Orthod (2017) (14)	☺	☹ (Execution: unclear treatment and growth simulation)	☺	☺	☹	☹ (Age and stadium of growth NA)	☹ (Execution: unclear treatment & growth simulation)	? (Execution: identical tooth models)	☹
Jang et al Angle Orthod (2009) (7)	☺	☹ (Only mean values, no assessment of the validity of the gold standard method)	☹ (Only mean values, no assessment of the validity of the gold standard method)	? (treatment time not reported)	☹	☺	☹ (Only mean values, no assessment of the validity of the gold standard method)	☹ (Only mean values, no assessment of the validity of the gold standard method)	☹
Nalcaci et al Korean J Orthod (2015) (8)	☺	☹ (Execution: only mean values tested)	? (Cephalograms used as reference standard; blinding not reported)	☺	☹	☹ (Execution: range of age NA, method of distalisation NA)	☹ (Execution: only mean values tested)	☺	☹
Talaat et al Eur J Orthod (2017) (9)	☺	☹ (Execution: only mean values tested)	☹ (Execution: cranial base superimposition compared to palate superimposition in growing patients)	☺	☹	☺	☹ (Execution: only mean values tested)	☺	☹
Vasilakos et al Sci Rep (2017) (2)	☺	? (Execution: comparison to an assumed gold standard)	☺	☺	?	☺	☺	☺	☺
Yun et al Korean J Orthod (2018) (15)	☺	☹ (No comparison, only mean values, no Bland-Altman plots, no exact description of the superimposition area)	☹ (Inappropriate testing)	☺	☹	☹ (Small sample size)	☹ (No comparison, only mean values, no Bland-Altman plots, no exact description of the superimposition area)	☹ (Inappropriate testing)	☹

Supplementary Table 3. General characteristics of the included studies presented in more detail.

Study name	Study type	Objectives	Sample size and sex	Age	Growth	Type of participants (serial casts)	Time between serial casts	Model acquisition
An et al J Orofac Orthop (2015) (3)	Retrospective (dental casts) // prospective methodological study	Identification of stable reference areas for superimposing 3D dental models in the mandible.	n = 10 (4M, 6F; 5 with and 5 without mandibular torus)	Mean: 24.9±10 (range:16.6-47.8) years	Non-growing	Pre- and post-orthodontic treatment: extraction of 4 premolars; patients with and without mandibular torus.	Mean: 33 months	Stone dental casts scanned by a surface scanner (KOD300, Orapix Co., Ltd., Seoul, Korea; ±0.05 mm resolution).
Becker et al J Orofac Orthop (2018) (6)	Retrospective (dental casts) // prospective methodological study	Evaluation of the agreement between two different matching approaches [control point (CP)-based vs. iterative closest point (ICP) matching] on the assessment of orthodontic treatment outcome.	n = 48 (22M, 26F)	Age range: 11–53 years	Growing and non-growing	Orthodontic treatment: patients with an initial indication for upper molar protraction, who completed treatment with an appliance coupled with two mini-screws inserted into the anterior palate.	Mean: 11.65 ± 7.55 months	Dental stone casts scanned by a surface scanner (Dentaurum Smart Optics Activity, Germany).
Cha et al Eur J Orthod (2007) (10)	Retrospective (sample) // prospective methodological study	Comparison of three-dimensional digital models superimposition with cephalometric superimposition.	n = 30 (6M, 24F)	Mean age: 17.7 (range: 11.1 - 29.8) years	Growing and non-growing	Pre and post orthodontic treatment: orthodontic treatment with extraction of 4 premolars.	Mean: 35.3 (range: 26 - 51) months	Dental casts scanned by a surface scanner (topometric and photometric 3D scanner, Breuckmann Inc., Germany, resolution 8μm, reliability ±15μm).
Chen et al Orthod Craniofac Res (2011) (11)	Prospective	Identification of a stable palatal region to superimpose serial maxillary dental models in adult extraction cases.	n= 15 (11M, 4F)	Mean: 25.8 (range: 21 - 41) years	Non-growing	Pre and during orthodontic treatment: extraction of maxillary first premolars to reduce protrusion; placement of 6 miniscrews (2 loaded, 4 unloaded); en masse retraction of anterior teeth.	Mean: 17 months (completion of the retraction)	Dental casts scanned by a surface scanner (3D spot laser scanner: LPX-1200; Roland DG, Hamamatsu, Japan).
Choi et al Angle Orthod (2010) (12)	Cross-sectional	Evaluation of the superimposition of digital 3D models using the palate surface as reference for measuring tooth movements as compared to direct cast measurements.	n= 20 (gender NA)	NA	NA	Simulated treatment: random movement using a wax set up.	No second dental models (simulation)	Dental casts scanned by a surface scanner (Orapix 3D scanner: laser slittyp noncontact 3D scanner, Orapix Co Ltd, Seoul, South Korea).
Choi et al Korean J Orthod (2012) (13)	Retrospective (sample) // prospective methodological study	To assess the validity of 3D digital model superimposition in the palate in patients treated with rapid maxillary expansion (RME) and maxillary protration headgear.	n = 30 (12M, 18F)	Mean age: 9.6±1.4 (range: 7.3 - 11.8) years	Growing	Pre and post orthodontic treatment: RME and maxillary protraction headgear treatment.	Mean: 8.4 ± 2.5 (range: 4.0 - 13.0) months	Dental casts scanned by a surface scanner (non-contact 3D optical scanner: Orapix, Orapix Co., Seoul, Korea; reliability, +/- 20μm).

Ganzer et al Eur J Orthod (2017) (14)	Retrospective (dental casts) // prospective methodological study	Evaluation of a superimposition technique (named RFD), based on simulated tooth movement and growth.	n = 16 (gender not mentioned)	NA	NA	Simulated treatment: simulation of space closure after extraction of the first premolars and of growth by morphological change of the palatal vault.	No second dental model (initial model artificially altered)	Dental casts scanned by a surface scanner (R700 desktop scanner: 3Shape, Copenhagen, Denmark).
Jang et al Angle Orthod (2009) (7)	Prospective	Evaluation of a superimposition method for maxillary digital 3D models.	n = 10 (4M, 6F)	Mean age: 20 (range: 15.6 - 27) years	Non-growing	Orthodontic treatment of maxillary protrusion including bilateral extraction of maxillary first premolars and placement of three miniscrews, ligated with a transpalatal arch to reinforce orthodontic anchorage.	NA	Dental casts scanned by a surface scanner (VMD-25, UNISN, Osaka, Japan; measuring pitch in the x and y directions: 0.25 mm, resolution in the z direction: range of 0.05 mm).
Nalcaci et al Korean J Orthod (2015) (8)	Retrospective (sample) // prospective methodological study	Evaluation of the reliability of measurements obtained after the superimposition of digital 3D models by comparing them with those obtained from lateral cephalomertric radiographs and photocopies of plaster models for the evaluation of upper molar distalization.	n = 20 (10M, 10F)	Mean age: 16 years	Growing	Orthodontic treatment: distalization of the first molars with an intraoral distalizer for Class II correction.	NA	Dental casts: scanned by surface scanner (R700 desktop scanner: 3Shape A/S, Copenhagen, Denmark).
Talaat et al Eur J Orthod (2017) (9)	Retrospective (sample) // prospective methodological study	Evaluation of the validity of 3D landmark-based palatal superimposition of digital models using Ortho Mechanics Sequential Analyser (OMSA) and comparison to the surface-based 3dMD superimposition of 3D dental models and the surface-based Invivo Dental superimposition of CBCTs.	n = 20 (gender NA)	Mean age: 12.3 +/-1.9 years (range: 8 - 15 years)	Growing	Orthodontic treatment: maxillary expansion through Hyrax palatal expanders.	3 months	Dental casts scanned by a surface scanner (Ortho Insight 3D laser scanner: version 5.1, Motionview, Hixson, TN). CBCT scans: 120 kV and 20 mA, with a scanning time of 2 seconds per section, an A2-90 scanning filter, a 25-cm field of view, and a 0.4-mm voxel size (model X, vision; GE Medical Systems, Milwaukee, WI).
Vasilakos et al Sci Rep (2017) (2)	Prospective	Evaluation of the accuracy and precision of the palatal areas, previously used for superimposition of maxillary 3D digital dental casts.	n = 16 (7M, 9F)	Median age at T0: 8.0 years (range: 6.0- 9.3 years)	Growing	Orthodontic treatment: placement of resin modified glass ionomer cement on occlusal surfaces of selected lower teeth to treat dental anterior cross bite.	Median: 15.1 months (range: 7.2- 21.8)	Dental casts scanned by surface scanner (3D surface scanner: Stripe light/ LED illumination, Cendres + Métaux SA, CH-2501 Biel/Bienne).
Yun et al Korean J Orthod (2018) (15)	Prospective	Repeatability of serial intraoral scanner derived 3D model superimposition for evaluation of orthodontic tooth movement.	n = 7 (gender NA)	Mean age: 22.0 +/- 8.4 years	Growing and non-growing	Orthodontic treatment with fixed orthodontic appliances (extraction and non-extraction cases).	1 month (day of bonding: T0; 1 month later: T1)	Intraoral scans using Trios (3Shape; Copenhagen, Denmark; accuracy: ±7–8 mm).

NA: not available, M: male, F: female

Supplementary Table 4. Superimposition-related characteristics of the included studies presented in more detail.

Study name	Superimposition Method	References for superimposition	Superimposition Software	Details of the superimposition protocol
An et al J Orofac Orthop (2015) (3)	Dental models: surface-based Lateral cephalograms: manually	Dental models: 1. the bilateral lingual surfaces of the alveolar bone of the premolar and molar area, 2. the lingual alveolar surface of the entire dentition, 3. the bilateral buccal and the lingual alveolar surfaces of the premolar and molar area, 4. the bilateral mandibular tori Lateral cephalograms: lower border of the mandible and symphysis	Dental models: Rapidform XOR3, INUS Technology, Seoul, Korea	Best fit
Becker et al J Orofac Orthop (2018) (6)	Dental models (CP superimposition): landmark-based Dental models (ICP superimposition): surface-based	Dental models with landmark-based matching: 10 landmarks located in the incisive papilla and rugae region Dental models with surface superimposition: borders for ICP delimited by the connecting outline of the following 5 landmarks: incisal papilla, right and left gingival margin of the first premolar and right and left gingival margin of the second molars	Dental models: Activity Orthodontics V2.7.04 (Dentaurum, Germany)	Landmark-based superimposition: Best fit on 10 landmarks ICP superimposition: Best fit, employed through ICP
Cha et al Eur J Orthod (2007) (10)	Dental models: surface-based Lateral cephalograms: manual	Dental models: all rugae, lateral limits located approximately 1-3 mm from the gingival margin of the posterior teeth, and posterior limit at the distal margins of the first permanent molars Lateral cephalograms: palatal plane registered at ANS	Dental models: Rapidform 2002, INUS Technology Inc., Seoul, Korea	Best-fit method, employed through a least mean squared technique using a software's function
Chen et al Orthod Craniofac Res (2011) (11)	Superimposition on minimum of 3 (max 4) unloaded miniscrews to evaluate stable regions in the palate (< 0.5 mm distance). Superimposition on the identified stable region (PVR) and comparison of tooth movement results with the miniscrew superimposition.	Dental models: 1. superimposition on three or four stable unloaded miniscrews, 2. superimposition on the following stable region (region with a deviation < 0.5mm): medial 2/3 of the third rugae and the area distal to it extending until the distal end of first molars (3D-palatal-vault-regional-technique: PVR)	Dental models: Rapidform2006; INUS Technology Inc., Seoul Korea	Best fit, employed through ICP
Choi et al Angle Orthod (2010) (12)	Dental models: surface-based	Dental models: the palate including the following area: all rugae, the lateral margins were located at least 5mm from the gingival margins of the posterior teeth bilaterally, the distal margin did not extend distally beyond the line in contact with the distal surfaces of the maxillary 2. molars bilaterally, the incisive papilla was excluded	Dental models: Rapidform 2002, INUS, Technology Inc, Seoul, South Korea	Best-fit method, employed through a least mean squared technique using a software's function
Choi et al Korean J Orthod (2012) (13)	Dental models: surface-based on a palatal area Lateral cephalograms: manual	Dental models: area including the palatal rugae and palatal slope separated by 5 mm from the gingival margins of the bilateral posterior teeth, and did not extend distally beyond the line in contact with the distal surfaces of the bilateral first molars Lateral cephalograms: on the palatal plane with anterior nasal spine (ANS) as the registration point	Dental models: Rapidform 2002, INUS Technology Inc., Seoul, Korea	Best-fit method, employed through a least mean squared technique using a software's function
Ganzer et al Eur J Orthod (2017) (14)	Dental models: surface-based in three steps	Dental models: all rugae, lateral limits located approximately 1-3 mm from the gingival margin of the posterior teeth, and posterior limit at the distal margins of the second premolars	Dental models: Finale surface® software, Iterative closest proximity algorithm (ICProx)	Best fit, employed through point to triangle technique followed by ICProx algorithm using two subsequent software's functions
Jang et al Angle Orthod (2009) (7)	Dental models: surface-based after landmark-based	Dental models: 1. Point: the midpoint on the line connecting the medial points of the right and left third palatal rugae. Surface: the surface of the palatal vault surrounded by two transverse and two anteroposterior lines. One of the transverse lines is 10 mm away distally from the third palatal rugae, and the other is 5 mm away mesially from the line in contact with the distal surfaces of the bilateral maxillary second molars. On the palatal side, the anteroposterior lines are 10 mm from the lines in contact with the palatal gingival margins of the posterior teeth bilaterally 2. Best fit on 3 loaded miniscrews. Two were placed on the palatal slopes bilaterally between the second premolar and the first molar. Another miniscrew placed on the paramedian region of the hard palate	Dental models: Imageware 9, UGS PLM Solutions, Plano, Tex	1. Registered at point A, the surface B of the subsequent dental cast was best-fitted to that of the initial dental cast using the least-square method (rugae-palate superimposition method) 2. Best fit on 3 miniscrews as stationary landmarks, employed through the least-squares method (miniscrew superimposition method)

Nalcaci et al Korean J Orthod (2015) (8)	Dental models: landmark-based Lateral cephalograms: manual	Dental models: three points of the incisive papilla area (the most anterior point, the most prominent point, the most posterior point) Lateral cephalograms: a line perpendicular to the sella-nasion (SN) plane at the intersection of the anterior wall of the sella turcica and the anterior clinoid process	Dental models: O3DM version 2 software	Best fit, employed through three points which are not in the same line
Talaat et al Eur J Orthod (2017) (9)	Dental models: Landmark-based or surface-based CBCT: surface-based	Dental models: three points (1. distal end of the incisive papilla, 2. and 3. arbitrary distal to the first point along the middle palatal raphe) or palatal surface CBCT: cranial base	Dental models: OMSA, 3dMD software Radiographic models: Invivo Dental software (version 5.1, Anatomage, San Jose, CA)	OMSA: best fit, employed through the creation of a plane passing through the 3 selected points 3dMD: best-fit of a palatal surface Invivo Dental: best fit of the cranial base
Vasilakos et al Sci Rep (2017) (2)	Dental models: surface-based	Dental models Area A: medial 2/3 of the third rugae and the area 5mm dorsal to them, Area B: superimposition on area A adding a 6mm wide stripe on the midpalate suture extending to the level of a line connecting the lingual grooves of the first permanent molars, Area C: superimposition on area A but starting anteriorly from the medial 2/3 of the second rugae, Area D: superimposition on the palate bordered by a line 5mm from all gingival margins and extending to the middle of the first permanent molars, Area E: superimposition on an area of similar dimension as area A but starting anteriorly at a line connecting the interproximal areas between the primary molars	Dental models: Viewbox 4 software (version 4.1.0.1 BETA, dHAL Software, Kifissia, Greece)	Best fit, employed through the iterative closest point algorithm (ICP) using a software's function
Yun et al Korean J Orthod (2018) (15)	Dental models: surface-based	Dental models: The palatal rugae and palatal slope separated by 5 mm from the gingival margins of the bilateral posterior teeth, and did not extend distally beyond the line in contact with the distal surfaces of the bilateral first molars	Dental models: Rapidform XOR3 (INUS Technology, Seoul, Korea)	NA

Supplementary Table 5. Analysis-related characteristics of the included studies presented in more detail.

Study name	Comparison/Control	Main outcome	Secondary outcomes	Type of analysis	Method error
An et al J Orofac Orthop (2015) (3)	Tooth movement assessed through surface-based superimposition of 3D dental models vs. Cephalometric radiographs	Differences in horizontal and vertical movements of both central incisor tips and first molar distal cusp tips (mean of bilateral measurements was used) between cephalometric and surface model superimposition.	Intrarater	Descriptive statistics only (medians, maximum, and all single measurements)	Intrarater on the whole process and sample (random error: Dahlberg's formula)
Becker et al J Orofac Orthop (2018) (6)	Tooth movement assessed through 10 landmarks superimposition vs. Surface-based superimposition of 3D dental models	Root mean squared distance (RMSD) between the registered landmarks and between the registered surfaces following the respective superimpositions. The linear association of corresponding tooth movements among the two matching approaches.	NA	Descriptive statistics (mean, standard deviation), tests for normality (assessment for skewness, kurtosis and ShapiroWilk), linear regression models (normality of the residuals and homogeneity of variance were tested in advance)	NA
Cha et al Eur J Orthod (2007) (10)	Tooth movement assessed through surface-based superimposition of 3D dental models vs. Cephalometric radiographs	Differences of the antero-posterior and vertical movement of the maxillary first molars and central incisors measured on superimposed cephalometric radiographs and on superimposed 3D digital models.	NA	Paired t-tests, scattergrams and regression lines	NA
Chen et al Orthod Craniofac Res (2011) (11)	Tooth movement assessed through surface-based superimposition of 3D dental models vs. superimposed 3D dental models on stable miniscrews	Identification of a palatal region with less than 0.5 mm deviation between two superimposed dental models (visual inspection of color maps).	Agreement between miniscrew and surface-based superimpositions in tooth movement assessment; Reproducibility of the surface-based superimposition.	Descriptive statistics and pairwise comparisons for the main outcome (unpaired t-test) and intra-class correlation coefficient (ICC) for intra- and inter-observer error	Intra and interrater (ICC)
Choi et al Angle Orthod (2010) (12)	Simulated tooth movement measurements made directly on plaster models vs. Surface-based superimposition of 3D dental models	Differences in tooth movements evaluated on superimposed digital 3D models and directly on plaster models.	Intrarater	Paired t-test, Pearson correlation analysis (including scatter plots)	Intrarater on the whole process and sample
Choi et al Korean J Orthod (2012) (13)	Tooth movement assessed through surface-based superimposition of 3D dental models vs. Cephalometric radiographs	Differences of the antero-posterior and vertical tooth movements measured on superimposed cephalometric radiographs and on superimposed 3D digital models.	Intrarater	Bland-Altman plots using 95% limits of agreement and intra-class correlation (ICC)	Intrarater on the whole process and sample
Ganzer et al Eur J Orthod (2017) (14)	Tooth movement assessed through surface-based superimposition of 3D dental models vs. Original value of simulated tooth movement measurements	Translation and rotations in the transversal axis (x), the mesio-distal axis (y) and the vertical axis (z). Calculation of the total movement (d).	Intrarater and interrater	Plot with the individual differences of each observer from the true value. Correlation statistics (mixed effects model with true value as a covariate) and intra-class correlation (ICC) for intra-observer error	Intrarater and interrater on the whole process and sample
Jang et al Angle Orthod (2009) (7)	Tooth movement assessed through landmark-based followed by surface-based superimposition of 3D dental models vs. superimposed 3D dental models on stable miniscrews	Displacement of the central incisors measured on the superimposing images by means of the miniscrew-superimposition method and the surface-based superimposition method.	Reproducibility (intraclass correlation coefficient)	Pearson's correlation analysis and paired t-test	Intraclass correlation

Nalcaci et al Korean J Orthod (2015) (8)	Tooth movement assessed through landmark-based superimposition of 3D dental models vs. Cephalometric radiographs	Anteroposterior movement of the maxillary first molars first and second premolars and central incisors.	Intrarater	Friedman test, Cronbach's alpha (intrarater)	Intrarater on 10 sets of randomly selected measurements
Talaat et al Eur J Orthod (2017) (9)	Tooth movement assessed through landmark-based superimposition vs. surface-based superimposition of 3D dental models vs. surface based-superimposition of CBCT radiographs	Differences of the superimposed digital models between the following points: R6 MB and L6 MB, right and left maxillary right first molar mesiobuccal cusp tips; R6 DB and L6 DB, right and left maxillary right first molar distobuccal cusp tips; R1 and L1, right and left midpoint of the incisal edges of the maxillary right central incisors; R3 and L3, right and left maxillary right canine cusp tips	Intrarater	Intra-class correlation (ICC), analysis of variance (ANOVA)	Intrarater on the whole process and sample
Vasilakos et al Sci Rep (2017) (2)	Tooth movement assessed through surface-based superimposition of 3D dental models on the gold standard area A vs. Other 4 areas (B, C, D, E).	Positional and rotational changes of one maxillary central incisor and both first permanent molars in three dimensions	Intra and interrater	Permutational multivariante analysis of covariance (MANCOVA) with factorial fixed or mixed effects models, Wicoxon signed- rank test, Monte Carlo asymptotic p-value (PERMANOVA), Permutational analysis of multivariante dispersions (PERMDISP), Bonferroni correction, Bland-Altmann method	Intrarater and interrater on the whole process and sample
Yun et al Korean J Orthod (2018) (15)	NA	Repeatability of linear and angular changes of the central incisors, canines, and first molars	NA	Intra-class correlation (ICC), random error (Dahlberg formula)	Intrarater on 7 patients

Supplementary Table 6. Results of the included studies presented in more detail.

Study name	Main results	Secondary outcome results	Conclusions	Limitations
An et al J Orofac Orthop (2015) (3)	With torus (absolute values) Area 1 vs. Ceph. Vertical. Incisors: mean 0.88 (max: .1.6) mm, molars: mean 1.04 (max: 2.7) mm / Horizontal. Incisors: mean 0.76 (max: 1.3) mm, molars: mean 0.82 (max: 1.9) mm Area 2 vs. Ceph. Vertical. Incisors: mean 0.9 (max: 1.5) mm, molars: mean 0.86 (max: 2.4) mm / Horizontal. Incisors: mean 0.58 (max: -0,9) mm, molars: mean 1.0 (max: -1.6) mm Area 3 vs. Ceph. Vertical. Incisors: mean: 0.92 (max: 1.9) mm, molars: mean 0.9 (max: 1.7) mm / Horizontal. Incisors: mean 0.78 (max: -1.6) mm, molars: mean 0.9 (max: -1.5) mm Area 4 vs. Ceph. Vertical. Incisors: mean: 0.16 (max: 0.4) mm, molars: mean 0.4 (max: -0.7) mm / Horizontal. Incisors: mean 0,4 (max: -0.6) mm, molars: mean 0.28 (max: -0.6) mm Without torus (absolute values) Area 1 vs. Ceph. Vertical. incisors: mean 1.36 (max: 3.0) mm, 0.76 (max: 1.3) mm, molars: mean 1.5 (max: 2.6) mm / Horizontal. Incisors: mean 0.92 (max: -2.2) mm, molars: mean 0.88 (max: -1.5) mm Area 2 vs. Ceph. Vertical. Incisors: mean 4.58 (max: 10.0) mm, molars: mean 2.28 (max: 4.3) mm / Horizontal. Incisors: mean 1.84 (max: -3.6) mm, molars: mean 2.12 (max: -3.2) mm Area 3 vs. Ceph. Vertical. Incisors: mean 2.28 (max: 4.0) mm, molars: mean 1.4 (max: 2.7) mm / Horizontal. Incisors: mean 1.26 (max: -2.6) mm, molars: mean 1.18 (max: -1.9) mm	NA	The tori seem to be more accurate for superimposition than the alveolar bone.	Only adult patients, sample size too small, comparison with cephalometric radiographs
Becker et al J Orofac Orthop (2018) (6)	RMSD landmark-based superimposition mean: 0.8, SD: 0.4 RMSD surface-based superimposition mean: 0.8, SD: 0.3 Incisors: R-transverse = 0.91, R-anteroposterior = 0.85, R-vertical = 0.69 Molars: R-transverse = 0.85, R-anteroposterior = 0.92, R-vertical = 1.04 ($p<0.01$)	NA	Landmark-based and an automated surface-matching approach may both allow for comparable results, though individual differences are evident.	Only mean values, no Bland-Altman plots, large age range, no method error, poor reporting
Cha et al Eur J Orthod (2007) (10)	Central incisor Ceph - Horizontal: mean= -2.7 ± 2.1mm (range: -7.0 - 1.0); 3D - Horizontal: mean= -2.7 ± 2.1mm (range: -7.0 - 0.9) p = 0.56 Ceph - Vertical: mean= 1.0 ± 1.6mm (range: -3.5 - 4.0); 3D - Vertical: mean= 0.9 ± 1.5mm (range: -3.3 - 3.8) p = 0.14 First molar Ceph - Horizontal: mean= 3.6 ± 1.6mm (range: 0.5 - 7.0); 3D - Horizontal: mean= 3.5 ± 1.6m (range: 0.3 - 6.7) p = 0.12 Ceph - Vertical: mean= -0.1 ± 1.3mm (range: -2.0 - 4.5); 3D - Vertical: mean= -0.2 ± 1.3mm (range: -2.4 - 3.7) p = 0.26 Correlation coefficients of cephalometric measurements with 3D cast measurements were greater than 0.990	NA	There is no significant difference between the results of superimpositions of 3D digital models compared to those of cephalometric radiographs.	Comparison with cephalometric radiographs, exclusion of measurements of tooth movements along the z-axis, no method error, no Bland Altman plots
Chen et al Orthod Craniofac Res (2011) (11)	According to the shown color maps the medial 2/3 of the third rugae and the regional palatal vault dorsal to it was the stable reference area identified.	Two out of eight comparisons between the two methods showed a statistically significant difference in tooth movement assessment, but this was not clinically significant (mean < 0.4 mm). An ICC > 0.98 indicated high intra- and inter-observer agreement.	The medial 2/3 of the third rugae and the palatal vault dorsal to it seem to be a stable superimposition reference in adult patients treated with premolar extractions.	Stable screws evaluated through linear measurements (0.5 mm allowance) and not through superimposition, deviation between structures visually assessed, results applicable only in non-growing patients, mean comparisons and not individual differences were assessed, the results of the validation/comparison were expected because the stable area was identified through the miniscrew superimposition

Choi et al Angle Orthod (2010) (12)	Mean difference of measurements on plaster models and digital 3D models Anteroposterior (x-axis): Right canine = -0.02 ±0.15, Right first premolar = -0.04 ±0.17, Right first molar = -0.03 ±0.17, Right first molar = 0.05 ±0.19, Left canine = 0.03 ±0.12, Left first premolar = 0.04 ±0.20, Left first molar = -0.04 ±0.12, Left first molar = -0.04 ±0.14 Transverse (y-axis): Right canine = -0.03 ±0.00, Right first premolar = 0.01 ±0.18, Right first molar = 0.00 ±0.20, Right first molar = -0.01 ±0.15, Left canine = 0.04 ±0.20, Left first premolar = 0.03 ±0.19, Left first molar = -0.03 ±0.14, Left first molar = 0.07 ±0.17 Vertical (z-axis): Right canine = 0.00 ±0.17, Right first premolar = 0.01 ±0.14, Right first molar = -0.02 ±0.11, Right first molar = -0.01 ±0.14, Left canine = -0.01 ±0.13, Left first premolar = 0.03 ±0.16, Left first molar = -0.01 ±0.12, Left first molar = 0.02 ±0.12	Intra-examiner error. The mean differences on the plaster model were 0.04 mm, 0.07 mm, and 0.08 mm along the x-, y-, and z-axes, respectively. On the digital model, the mean difference was 0.01 mm along all axes.	There is no significant difference between measurements made directly on the plaster models and on superimposed digital 3D models.	In vitro study, no real orthodontic treatment, identical palatal vault and teeth
Choi et al Korean J Orthod (2012) (13)	ICC: antero-posterior movement of incisors = 0.956, molars = 0.941, vertical movement of incisors = 0.748, molars = 0.717; Bland-Altman plots: antero-posterior movement of incisors LoA = -1.3 - 0.8 mm (mean: -0.2), molars LoA = -1.3 - 1.1 mm (mean: -0,1), vertical movement of incisors LoA = -1.5 - 3.1 mm (mean: 0.8), molars LoA = -1.3 - 2.1 mm (mean: 0.4)	Intra-examiner correlation coefficients of cephalometric variables were greater than 0.934, and those of 3D variables were greater than 0.996.	The 3D model superimposition is as clinically reliable for assessing antero-posterior tooth movement as cephalometric superimposition in cases treated by RME and maxillary protraction headgear. However, vertical tooth movements did not demonstrated adequate agreement.	Comparison with cephalometric radiographs
Ganzer et al Eur J Orthod (2017) (14)	Total tooth movement [mm]: Abs mean error = 0.0225±0.03, Mean error = −0.0017 (range = −0.07 - 0.08), ICC (95% CI) = 0.9990, 0.9998 Translation x axis [mm]: Abs mean error = 0.0152 ± 0.02, Mean error = −0.0049 (range = −0.06 - 0.09), ICC (95% CI) = 0.9985, 0.9997 Translation y axis [mm]: Abs mean error = 0.0208 ± 0.03, Mean error = −0.0033 (range = −0.09 - 0.06), ICC (95% CI) = 0.9991, 0.9998 Translation z axis [mm]: Abs mean error = 0.0240 ± 0.04, Mean error = 0.0020 (range = −0.21 - 0.15), ICC (95% CI) = 0.9762, 0.9951 Rotation x axis (disto-mesial tipping) [degree]: Abs mean error = 0.0291 ± 0.04, Mean error = −0.0241 (range = −0.35 - 0.11), ICC (95% CI) = 0.9998, 1.0000 Rotation y axis (buccal-palatal tilting) [degree]: Abs mean error = 0.0134 ± 0.02, Mean error = 0.0021 (range = −0.13 - 0.06), ICC (95% CI) = 0.9999, 1.0000 Rotation z axis (around the tooth axis) [degree]: Abs mean error = 0.0215 ± 0.03, Mean error = 0.0098 (range = −0.12 - 0.13), ICC (95% CI) = 0.9999, 1.0000	Intrarater and interrater	The surface-based superimposition method seems to be valid when tested in duplicated, artificially changed 3D digital models.	No actual serial models, the palate was changed to simulate growth, but no details are provided
Jang et al Angle Orthod (2009) (7)	Miniscrew-superimposition. Mean: 3.22 ± 1.94 mm Surface-based superimposition. Mean: 3.14 ± 2.04 mm, p = 0.26 r = 0.99	Intraclass correlation coefficient: 0.997 for the miniscrew- and 0.998 for the surface-based superimposition	The maxillary dental casts might be superimposed reliably using the medial points of the third rugae and the palatal vault.	Only mean values, no Bland-Altman plots, small sample size, no assessment of the validity of the gold standard method, treatment time not mentioned, no proper/detailed method error assessment

Nalcaci et al Korean J Orthod (2015) (8)	Distalization of tooth 26 (mm) Cephalograms: 4.0±1.36, 3D models: 4.52±1.27 Distalization of tooth 21(mm) Cephalograms: 0.63 ±0.52, 3D models: 0.48 ±0.39	Intraexaminer	The study claimed no significant differences between the mean results of each superimposition method.	Comparison with cephalometric radiographs, comparison of mean values without showing/testing individual measurements
Talaat et al Eur J Orthod (2017) (9)	Mean differences between methods (mm) R6 MB: Surface & CBCT n.s. (−0.02), Surface > Landmark (0.25), CBCT > Landmark (0.27) R6 DB: Surface < CBCT (−0.33), Surface > Landmark (0.21), CBCT > Landmark (0.54) L6 MB: Surface < CBCT (−0.22), Surface & Landmark n.s. (0.07), CBCT > Landmark (0.28) L6 DB: Surface & CBCT n.s. (−0.14), Surface & Landmark n.s. (0.07), CBCT & Landmark n.s. (0.21) R3: Surface < CBCT (−0.34), Surface & Landmark n.s. (−0.06), CBCT & Landmark n.s. (0.28) L3: Surface & CBCT n.s. (−0.14), Surface & Landmark n.s. (−0.12), CBCT & Landmark n.s. (0.02) R1: Surface < CBCT (−0.30), Surface & Landmark n.s. (0.14), CBCT > Landmark (0.44) L1: Surface < CBCT (−0.26), Surface & Landmark n.s. (0.12), CBCT > Landmark (0.38)	Intrarater	Regarding the results landmark-based superimposition seems to deliver similar results compared to the other methods.	Mean differences assessed, no Bland-Altman, cranial base superimposition compared to palate superimposition in growing patients
Vasilakos et al Sci Rep (2017) (2)	Accuracy (mean of absolute differences of tooth movement measurements performed at two different time points) Linear measurements (mm): Area A: Incisor: x= 0.18, y= 0.09, z= 0.19; Molar R: x= 0.32, y= 0.53, z= 0.51; Molar L: x= 0.36, y= 0.52, z= 0.58 Area B: Incisor: x= 0.32, y= 0.27, z= 0.20; Molar R: x= 0.11, y= 0.27, z= 0.20; Molar L: x= 0.09, y= 0.22, z= 0.22 Area C: Incisor: x= 0.25, y= 0.16, z= 0.20; Molar R: x= 0.05, y= 0.25, z= 0.29; Molar L: x= 0.08, y= 0.21, z= 0.32 Area D: Incisor: x= 0.11, y= 0.08, z= 0.08; Molar R: x= 0.02, y= 0.13, z= 0.11; Molar L: x= 0.02, y= 0.08, z= 0.08 Area E: Incisor: x= 0.57, y= 0.41, z= 0.59; Molar R: x= 0.16, y= 0.67, z= 0.35; Molar L: x= 0.10, y= 0.78, z= 0.31 Angular measurements (°): Area A: Incisor: x= 0.58, y= 0.78, z= 0.53; Molar R: x= 0.97, y= 0.90, z= 1.03; Molar L: x= 0.95, y= 1.13, z= 1.18 Area B: Incisor: x= 1.22, y= 1.68, z= 0.69; Molar R: x= 0.70, y= 0.53, z= 0.73; Molar L: x= 0.57, y= 0.50, z= 0.76 Area C: Incisor: x= 0.82, y= 0.84, z= 0.68; Molar R: x= 0.48, y= 0.63, z= 0.71; Molar L: x= 0.58, y= 0.93, z= 0.77 Area D: Incisor: x= 0.47, y= 0.54, z= 0.30; Molar R: x= 0.34, y= 0.17, z= 0.34; Molar L: x= 0.40, y= 0.22, z= 0.53 Area E: Incisor: x= 1.60, y= 0.90, z= 1.72; Molar R: x= 1.80, y= 0.85, z= 1.48; Molar L: x= 1.73, y= 0.91, z= 1.70	Intrarater and interrater	The medial part of the third rugae and a small area dorsal to it showed adequate accuracy for superimposing serial casts of growing patients. The other reference areas cannot be suggested.	Comparison to an assumed gold standard
Yun et al Korean J Orthod (2018) (15)	Method errors (repeatability) of the linear measurements Anteroposterior (mm): Central incisor = 0.08; Canine = 0.13; First molar = 0.16 Vertical (mm): Central incisor = 0.16; Canine = 0.08; First molar = 0.13 Lateral (mm): Central incisor = 0.06; Canine = 0.04; First molar = 0.13 Method errors (repeatability) of the angular measurements Mesiodistal (°): Central incisor = 0.69; Canine = 0.50; First molar = 0.99 Labiolingual (°): Central incisor = 0.80; Canine = 0.71; First molar = 0.83 Rotation (°): Central incisor = 0.76; Canine = 0.85; First molar = 0.48 In all cases: $r > 0.978$, $p < 0.001$	NA	3D superimposition of serial 3D dental models may provide repeatable evaluation of orthodontic tooth movement.	Measurements are based on landmark identification, no comparison, only mean values, no Bland-Altman plots, small sample size

Supplementary text. Closely related studies that are not included and reasons for this.

• Ashmore et al Am J Orthod Dentofacial Orthop. (2002) is not included because there is no comparison group.

• Becker et al Clin Oral Investig. (2018) is not included because it deals about 2-dimensional superimpositions and not about 3-dimensional.

• Hayashi et al J Biomech. (2002) is not included because it is a case report and has no comparison included.

• Hoggan et al Am J Orthod Dentofacial Orthop. (2001) is not included because it deals about 2-dimensional superimpositions and not about 3-dimensional.

• José Vinas et al Int Orthod. (2018) is not included because case reports are not regarded in this review.

• Miller et al Orthod Craniofac Res. (2003) is not included because the same model is used to assess landmark-based superimposition error. There is no real or simulated change on the model.

• Schmidt et al Ann Biomed Eng. (2018) is excluded because the main purpose of the study was to test orthodontic tooth movement assessment through two numerical models that were based on specific biological concepts and through these mean values were obtained using data from the literature. Four palatal surface-based superimposition techniques were used in order to compare their mean outcomes with that of the numerical models and with reference values found in the literature. The way the study was performed and reported did not allow a detailed evaluation of any specific superimposition technique as this was beyond the scope of the study. Therefore we decided to exclude this study from our review.

• Thiruvenkatachari et al Am J Orthod Dentofacial Orthop. (2009) is not included because there is no comparison. They compare their conclusion with those of another cephalometric study in a qualitative manner.

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