Original Article

A comparison of patient experience, chair-side time, accuracy of dental arch measurements and costs of acquisition of dental models

Olja Glisic[a]; Louise Hoejbjerre[a]; Liselotte Sonnesen[b]

ABSTRACT

Objective: To compare patient experience, chairside time, dental arch distances, and costs of dental models derived from intraoral scans and alginate impressions in pre-orthodontic children and young adolescents.

Materials and Methods: Fifty-nine children and young adolescents (9–15 years, mean: 12.70 years) had an intraoral scan and an alginate impression prior to orthodontic treatment. During the procedures, chairside time was registered in minutes and patient experience was assessed by a Visual Analogue Scale questionnaire. Four maxillary dental arch distances were measured on digital models, on plaster casts, and directly in the mouth (intraoral). The cost of each procedure was presented graphically. Differences between the two procedures were tested by paired *t*-test and general linear model.

Results: Patient experience was statistically better during intraoral scan compared with alginate impression regarding comfort, gag reflex, breathing, smell/sound, taste/vibration, and all statements concerning anxiety ($P < .05$). No significant difference in chairside time between the two procedures was found. No statistically significant differences in dental arch distances between digital models and plaster casts were found, but dental arch distances measured intraorally differed significantly from both digital models and plaster casts ($P < .05$). Cost calculation showed that the digital procedure was 10.7 times more expensive than the conventional procedure initially and, that after 3.6 years, the two procedures were equal in cost.

Conclusions: Children preferred intraoral scan rather than alginate impression. Chairside time was equal for the two procedures as were the measurements of maxillary dental arch distances. The two procedures were equal in cost at 3.6 years. (*Angle Orthod.* 2019;89:868–875.)

KEY WORDS: Children; Intraoral scan; Alginate impression; Experience; Chairside time; Cost calculation

INTRODUCTION

Prior to orthodontic diagnostics and treatment planning, dental models are very often used to evaluate the dentition and occlusion.[1] The conventional alginate impression is generally considered unpleasant,[2] especially for those with a sensitive gag reflex, and it has previously been shown that patient experience at the beginning of an orthodontics treatment is important for the compliance and treatment outcome.[3] The patient experience of intraoral scan compared with conventional alginate impression in young orthodontic patients has only been investigated in a few studies.[4,5]

The chairside time during treatment may also influence the patient experience.[6] The time requirements for intraoral full-arch scans compared to conventional alginate impression differ and only a few studies have been performed involving children and young adolescents.[4,5] Therefore, further investigations of patient experience and chairside time between alginate impression and intraoral scan may be needed

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in children and young adolescents with severe malocclusion prior to orthodontic treatment.[7]

Patient experience and chairside time may not be the only factors to consider before implementing a new technique in the clinic, such as using an intraoral scanner. The reliability and cost also may be considered. It has been proposed that digital models from intraoral scanning reproduce the intraoral structures more accurately compared with plaster casts[6] but no studies have so far compared both techniques with direct intraoral measurements. Additionally, one study proposed that the cost of an intraoral scanner can be recovered in reduced overhead and increased practice efficiency and may pay for itself within two years,[8] but further studies may be needed to evaluate the economic perspective.

The aim of the present study was to compare patient experience, chairside time, dental arch distances, and costs of dental models derived from digital intraoral scans and alginate impressions in pre-orthodontic children and young adolescents with severe malocclusion.

MATERIALS AND METHODS

All pre-orthodontic children and adolescents who met the inclusion criteria were recruited from the Postgraduate Clinic in Orthodontics, Department of Odontology, University of Copenhagen in the period from September 2016 to October 2017. The inclusion criteria were: (1) children and adolescents between 9 and 15 years, (2) no previous orthodontic treatment or experience with digital intraoral scan or alginate impression technique, and (3) indication for orthodontic treatment according to the Danish Procedure for Screening the Child Population for Severe Malocclusion entailing Health Risks.[9] Patients who declined participation and patients with craniofacial syndromes or other general diseases were excluded.

The total group comprised 59 patients, 28 girls, and 31 boys, aged 9 to 15 years (mean: 12.83 years and 12.56 years, respectively). Informed oral consent was obtained from legal guardians and assent was obtained from patients prior to conducting the study. The protocol was approved by The Danish Data Protection Agency (SUND-2016-77). Power analysis using the mean prevalence regarding validity, time consumption, and patient comfort reported in recent studies[4,10–12] showed that at least 42 subjects were required to have sufficient power (90%) to identify statistically significant differences at the 5% level of significance.

Two operators performed the following procedures:

Alginate Impression and Intraoral Scan

Each patient had an alginate impression at the first appointment and an intraoral scan at the following appointment (performed by the same operator), prior to orthodontic treatment.

Alginate impressions were obtained with a 180-hour irreversible hydrocolloid impression material (GC Aroma Fine Plus fast set; GC Corporation, Tokyo, Japan) and standard perforated metal trays (Zenith Dental, Agerskov, Denmark) with the patient seated upright. Immediately after the impressions, a wax bite registration (Alminax; Associated Dental Products Ltd, Swindon, Wiltshire, UK) and a silicone bite registration (Occlufast Rock, Zhermack S.p.A, Badia Polesine, Italy) with the patient's teeth in centric occlusion were performed. The alginate impressions were poured with plaster (Hinrizit, Ernst Hinrichs, Goslar, Germany).

The intraoral scan was performed using 3Shape scanner (3Shape, TRIOS Classic, version 1.4.6.0, Copenhagen, Denmark) with the patient lying down, in the following sequence: lower jaw, upper jaw, and bite registration, according to the manufacturer's recommendation. The examiners had no prior experience with intraoral scanning but received 10 hours of theoretical instruction and hands-on intraoral training on five subjects before scanning the first patient. They were thereby equally calibrated.

Patient Experience

Immediately after taking the alginate impression and performing the intraoral scan, the patients were asked to complete a questionnaire regarding comfort and anxiety on a modified 100-mm Visual Analogue Scale (VAS) with elements from face rating scales,[13,14] including a smiling face at the lowest score (0 mm) and a sad face without tears at the highest score (100 mm). Each VAS score was measured to the nearest millimeter.

Comfort was evaluated by seven questions regarding time perception, comfort, gag reflex, breathing, smell/sound, taste/vibration, and temperature during the procedures (Figure 1).[4,15] Anxiety was evaluated by six statements: feeling uneasy, feeling insecure, feeling upset, feeling afraid, feeling nervous, and feeling happy (Figure 2).[16]

Chairside Time

The chairside time was measured to the nearest minute during the procedures. For the alginate impression, the chairside time included alginate mixing with the water, impressions of the upper and lower arches and bite registrations, as well as any impressions that needed to be retaken. For the intraoral scan, the chairside time included scans of the upper and lower arches including the palate, bite registration, and intermediate trimming of the scan as well as any scans that needed to be retaken.

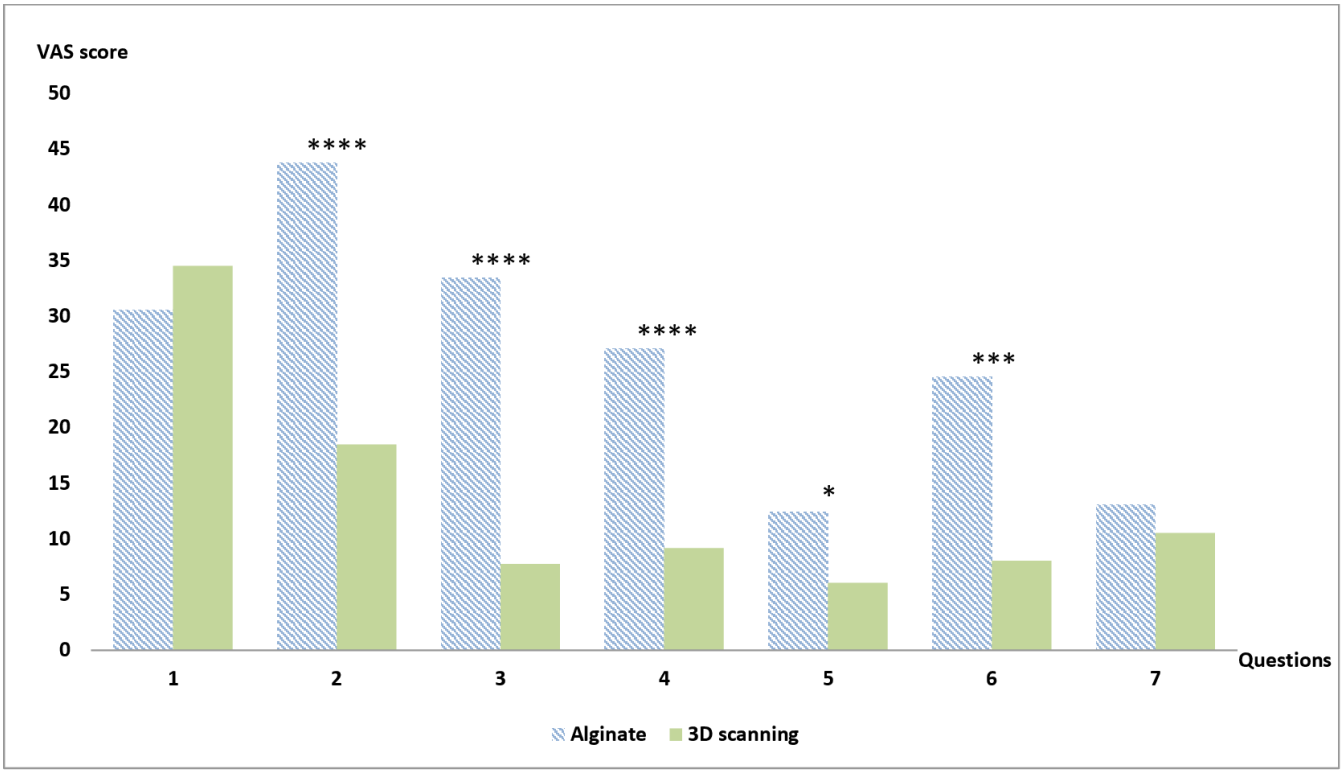

Figure 1. Patient comfort evaluated by seven questions:[4, 15] (1) Did the impression/intraoral scan take a long time to make? (2) Was it uncomfortable to have the impression/intraoral scan taken? (3) Was your gag reflex triggered while the impression/intraoral scan was taken? (4) Was it difficult to breathe while the impression/intraoral scan was taken? (5) Were you bothered by the smell/sound of the impression/intraoral scanner material? (6) Were you bothered by the taste/vibrations of the impression material/intraoral scanner? (7) Were you bothered by the temperature of the impression material/intraoral scanner?

Dental Arch Distances

Maxillary dental arch distances were measured directly in the mouth (I), on the plaster cast (G), and on the digital model (S) to the nearest 0.01 mm (Figure 3). An intraoral digital caliper (G&H Orthodontics, Franklin, IN, USA) was used to measure the distances in the mouth and on the plaster cast. On the digital models, the 3Shape software was used to measure the distances (OrthoSystems 2015-1, Version 1.6.1.10, Patch 10). The following four distances were registered in all three settings:[17]

TC3: Distance between the cusp tips of the permanent upper canines

TC6: Distance between the mesiofacial cusp tips of the permanent upper first molars

TC6,3+: Distance between the mesiofacial cusp tip of the permanent upper right first molar and the cusp tip of the permanent upper right canine

TC+3,6: Distance between the mesiofacial cusp tip of the permanent upper left first molar and the cusp tip of the permanent upper left canine

Costs Calculation

The cost of both procedures was estimated on an assumption of 310 dental models per year, according to the recommendation of the annual number of new patients for two full-time municipal Specialists in Orthodontics in Denmark. The monetary evaluations for each of the two procedures included the initial cost of the equipment and the accumulative yearly cost. The accumulative yearly cost was calculated by adding the price of materials and other expenses for the 310 models per year for each of the procedures.

The initial equipment for alginate impression included impression trays, alginate load on trays, spatulas, and an alginate mixer (Hauschild Dental, AM-501; 2017, Hamm, Germany). Materials and other expenses for manufacturing plaster casts included alginate powder, bite registration material, disinfection agents, and laboratory cost of plaster cast manufacturing.

The initial equipment for intraoral scanning included a computer (Alienware, Dell Headquarters, Round Rock, TX, USA), software (3Shape Ortho Analyzer), and 3D intraoral scanner (3Shape, TRIOS 3). Materials

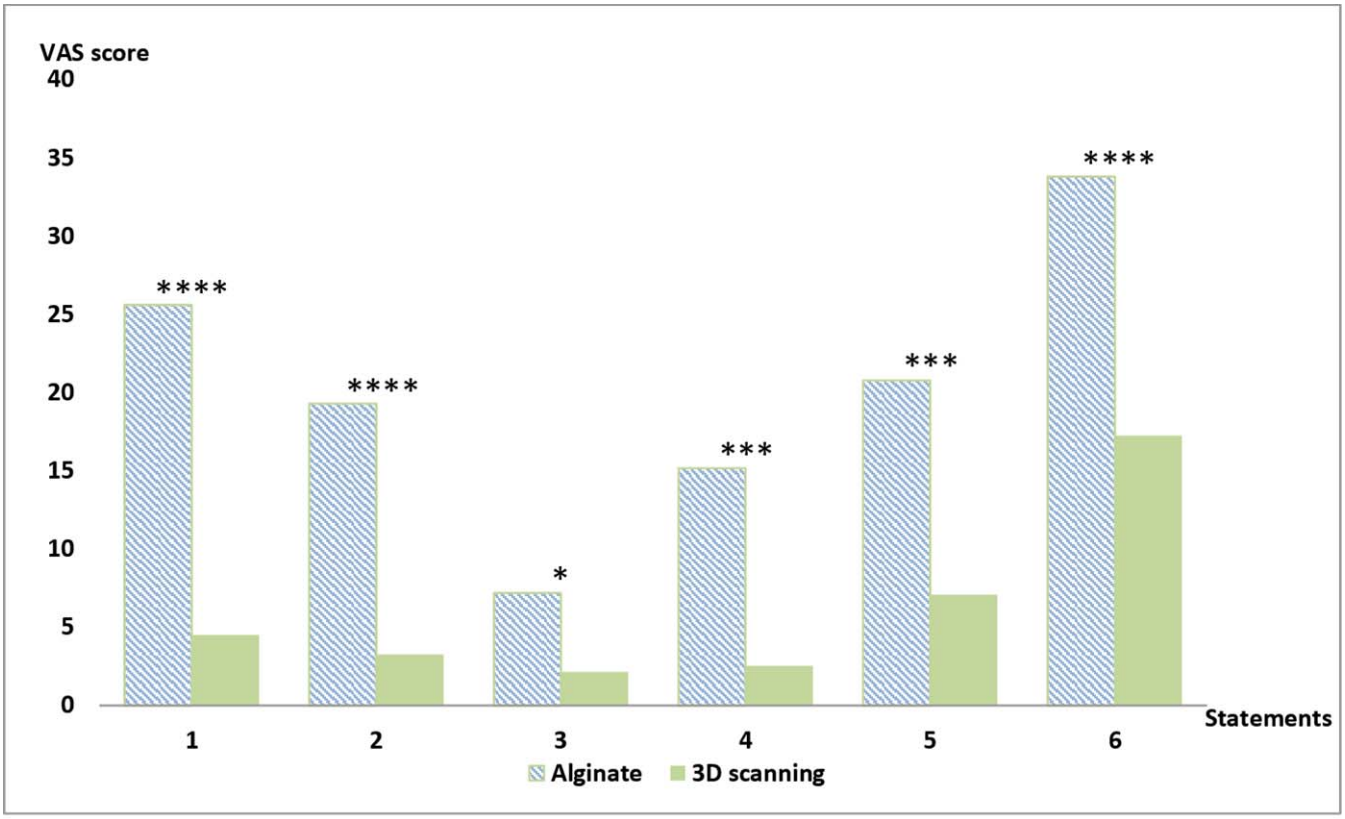

Figure 2. Patient anxiety evaluated by six statements:[16] (1) I felt uneasy while the impression was being taken/during the scanning. (2) I felt insecure while the impression was being taken/during the scanning. (3) I felt upset while the impression was being taken/during the scanning. (4) I felt afraid while the impression was being taken/during the scanning. (5) I felt nervous while the impression was being taken/during the scanning. (6) I felt happy while the impression was being taken/during the scanning.

and expenses for producing 3D models included scanner tip and software update fees.

All prices included were list prices with no economic deals and no discounts included in the calculation. The present study did not incorporate costs associated with replacement of the equipment.

Reliability and Method Error

The intra- and inter-observer reliability was determined by repeating all measurements after 4 weeks on 25 randomly selected plaster casts and 25 randomly selected scans.

No systematic error was found tested by paired *t*-test. The method error ranged from 0.001 to 0.050[18] and the reliability ranged from 0.99 to 1.[19]

Statistical Analyses

The statistical analyses were performed using SAS (v 9.4, Cary, NC, USA) software. The results of the tests were considered to be significant at $P < .05$.

The continuous data were tested by Q–Q plots on the residuals and was normally distributed. Age and gender distribution was tested by a *t*-test and an exact test based on binominal distribution. Differences in patient experience and the effect of age and gender were assessed by General Linear Model. Differences in dental arch distances and chairside time were assessed by paired *t*-test. Description of costs was presented graphically.

RESULTS

The gender distribution was: 47.5% girls and 52.5% boys. There were no significant differences between gender and age.

Patient Experience

VAS scores were significantly higher for alginate impressions compared to intraoral scans for questions (Figure 1) and statements (Figure 2) concerning comfort ($P < .0001$), gag reflex ($P < .0001$), breathing ($P < .0001$), smell/sound ($P = .0266$), taste/vibration ($P = .0002$), feeling uneasy ($P < .0001$), insecure ($P < .0001$), upset ($P = .0182$), afraid ($P = .0001$), nervous ($P = .0005$), and happy ($P < .0001$). No significant

differences were found between VAS scores concerning time perception ($P = .368$) and temperature ($P = .4259$).

There were no significant differences between age/gender and the VAS scores.

Chairside Time

There were no significant differences in chairside time between the two procedures ($P = .916$, Table 1).

Dental Arch Distances

The intraoral distances were significantly shorter compared with the measurements on the plaster casts and on the digital models between the upper right and left canine (ITC3/GTC3; ITC3/STC3) and between the upper first molar and upper canine on the right side (ITC6,3+/GTC6,3+; ITC6,3+/STC6,3+) ($P = .0257$, $P = .0098$; $P = .0207$, $P = .0011$ respectively, Table 2). No significant differences were found between the plaster casts and the digital models (Table 2).

Costs

At the initial stage, the digital procedure was 10.7 times more expensive than the conventional procedure. After 3.6 years, the two procedures were equal in cost (Figure 4).

DISCUSSION

Few studies have compared intraoral scans and alginate impressions in young orthodontic patients[4,5] and, as most orthodontic patients are children and adolescents,[20] this age group with severe malocclusions seems relevant to study. Additionally, measurements on digital models and plaster casts compared with direct intraoral measurements have not been reported previously.

Patient Experience

In the present study, the alginate impression was significantly more uncomfortable than the intraoral scan. This was in agreement with one study on adults,[15] whereas variable results between different scanners regarding comfort were found in two other studies on children and adolescents.[4,5] In the present study, the patients showed statistically more gag reflex and difficulties in breathing during the alginate impression compared with the intraoral scan, whereas no statistical difference was found in a study of 10- to 17-year-old patients.[4] Furthermore, in the present study, the children and young adolescents were more bothered by the smell and taste during the alginate impression, whereas no significant difference in perception of the temperature was found during the alginate impression compared with the intraoral scan. The findings have not been reported before in children but the differences in smell and taste were in agreement with a study on adults,[15] whereas the finding regarding temperature was in disagreement with a study on adults.[15]

In the present study, the anxiety and stress levels of the children and adolescents were significantly higher for the alginate impression compared with the intraoral scan. This was in disagreement with recent studies on adults,[15] children, and adolescents[4] that showed no

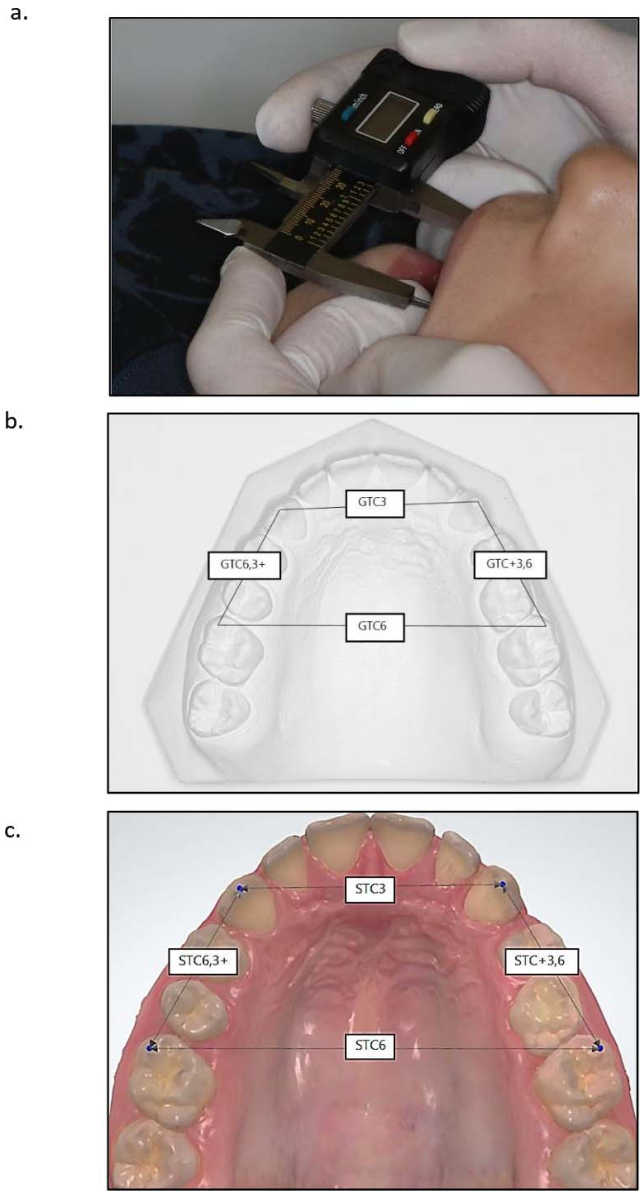

Figure 3. Illustration of measurements intraorally (a), on plaster casts (b), and on digital models (c). The measurements are defined previously.[17, 25]

Table 1. Comparison of the Chairside Time (Min) Between the Alginate Impression and the Intraoral Scan

Alginate Impression				Intraoral Scan				
Mean	Min.	Max.	SD[a]	Mean	Min.	Max.	SD	*P* Value
11.92	7	33	4.62	12.08	6	49	6.55	.916

[a] SD indicates standard deviation.

significant differences in patient anxiety and stress levels during the two procedures. An explanation of the findings in the present study might be that the accompanying parents' dental anxiety or general state of anxiety had affected the child.[21,22]

The patients' experience of a dental appointment is influenced by numerous factors. One factor is the feeling of being in control,[3] which appeared easier to achieve during the intraoral scan, thus resulting in a higher acceptance of this procedure. An explanation of this might be that it was possible to take breaks during the scan sequence and that the patient could follow the scan sequence on the computer. This is not possible during an alginate impression. This may affect the child's confidence in the dentist during treatment[3] and have an effect on treatment cooperation and success.[3]

Chairside Time

The time measurements in the present study were registered to the nearest minute, as this was considered clinically relevant. No significant difference in chairside time between the intraoral scan and the alginate impression was found in the present study. This was in disagreement with previous studies in both adults and children, where chairside time for some intraoral scanners was significantly longer compared with the alginate impressions in some studies[4–6,23] and significantly shorter in at least one other study.[15] Different types of scanners and continuous improvement of

Table 2. Comparison of the Maxillary Dental Arch Measurements Between the Plaster Cast (G), the Digital Scan (S) and Intraorally (I)[a–m]

Comparison of Dental Arch Measurements	N	Mean	Min	Max	SD	Lower 95% Confidence Limit	Upper 95% Confidence Limit	*P* Value
Intraoral vs. plaster cast								
ITC3-GTC3	39	−0.2	−1.49	1.22	0.54	−0.37	−0.03	**.0257**
ITC6-GTC6	59	0.01	−1.23	1.66	0.57	−0.14	0.16	.91
ITC6,3+-GTC6,3+	40	−0.28	−1.39	1.23	0.65	−0.49	−0.07	**.0098**
ITC+3,6-GTC+3,6	40	−0.14	−1.69	1.28	0.72	−0.38	0.09	.217
Intraoral vs. scan								
ITC3 – STC3	39	−0.2	−1.73	0.79	0.51	−0.37	−0.03	**.0207**
ITC6 – STC6	59	−0.03	−1.3	1.67	0.58	−0.19	0.12	.669
ITC6,3+ – STC6,3+	40	−0.36	−1.67	1.34	0.65	−0.57	−0.16	**.0011**
ITC+3,6 – STC+3,6	40	−0.14	−1.72	1.29	0.69	−0.36	0.08	.2187
Plaster cast vs. scan								
GTC3 – STC3	39	0	−0.58	0.6	0.29	−0.09	0.09	.98
GTC6 – STC6	59	−0.04	−0.47	0.53	0.23	−0.1	0.02	.173
GTC6,3+ – STC6,3+	40	−0.08	−0.73	0.48	0.28	−0.17	−0.01	.0736
GTC+3,6 – STC+3,6	40	0.01	−0.49	1.59	0.38	−0.11	0.13	.9021

[a] SD indicates standard deviation.
[b] ITC3 is the distance between the cusp tips of the permanent upper canines measured intra-orally.
[c] ITC6 is the distance between the mesiofacial cusp tips of the permanent first upper molars measured intra orally.
[d] ITC6,3+ is the distance between the cusp tip of the permanent first upper right molar and the cusp tip of the permanent upper right canine measured intra orally.
[e] ITC+3,6 is the distance between the cusp tip of the permanent first upper left molar and the cusp tip of the permanent upper left canine measured intra orally.
[f] GTC3 is the distance between the cusp tips of the permanent upper canines on plaster casts.
[g] GTC6 is the distance between the mesiofacial cusp tips of the permanent first upper molars on plaster casts.
[h] GTC6,3+ is the distance between the cusp tip of the permanent first upper right molar and the cusp tip of the permanent upper right canine on plaster casts.
[i] GTC+3,6 is the distance between the cusp tip of the permanent first upper left molar and the cusp tip of the permanent upper left canine on plaster casts.
[j] STC3 is the distance between the cusp tips of the permanent upper canines measured on digital models.
[k] STC6 is the distance between the mesiofacial cusp tips of the permanent first upper molars measured on digital models.
[l] STC6,3+ is the distance between the cusp tip of the permanent first upper right molar and the cusp tip of the permanent upper right canine measured on digital models.
[m] STC+3,6 is the distance between the cusp tip of the permanent first upper left molar and the cusp tip of the permanent upper left canine measured on digital models.

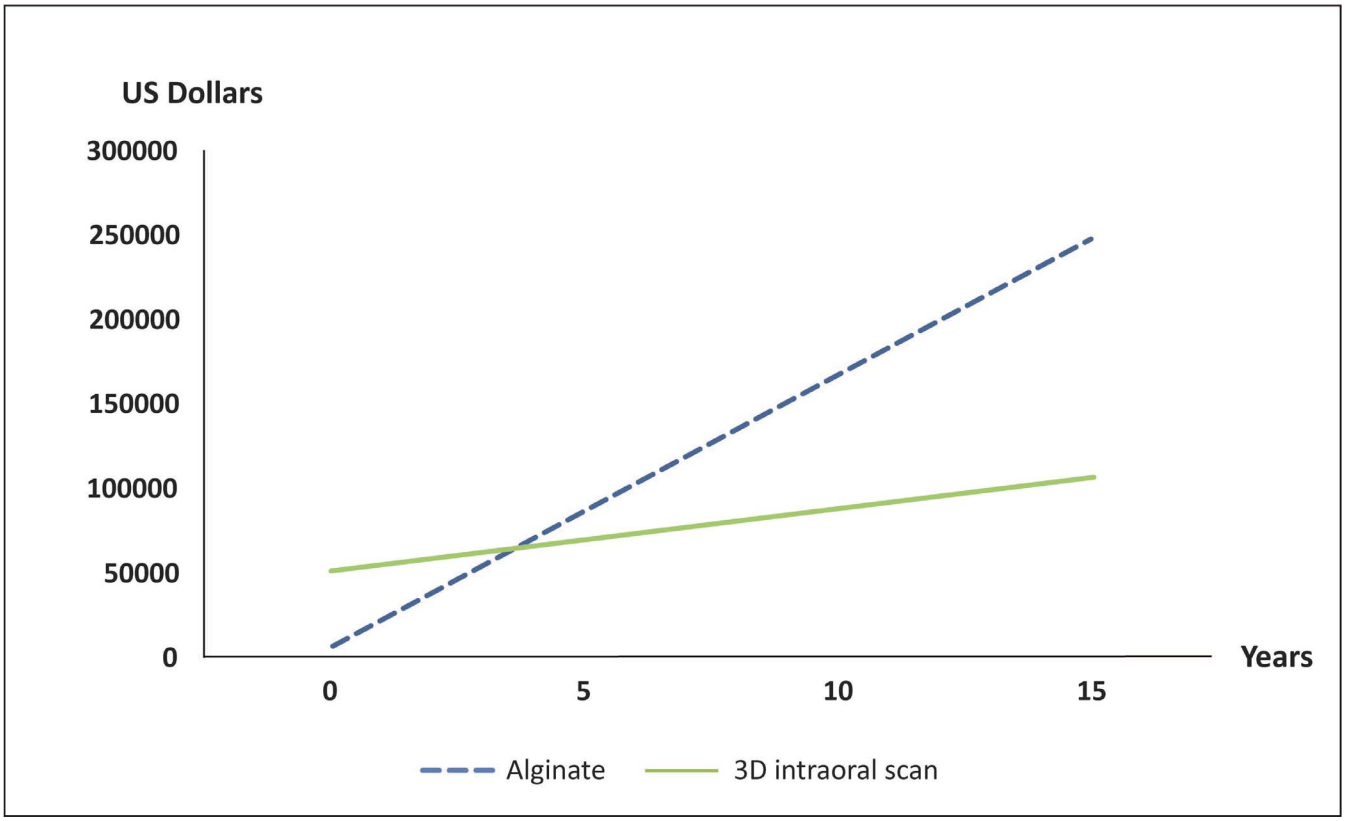

Figure 4. Graphic illustration of the cost for the two procedures illustrating the starting point, linear accumulation, and the intersection at 3.6 years.

digital scanning technology may explain the disagreement between the present and previous studies.

Dental Arch Distances

In the present study, no statistically significant differences in the maxillary dental arch distances were found between the digital models and plaster casts. Previous studies have evaluated various parameters regarding validity, reliability, and reproducibility of digital models compared to plaster casts.[11,23] Some studies found that the anterior Bolton ratio and linear measurements including the tooth widths differed significantly between digital models and plaster casts,[11,24] whereas other studies found that linear tooth measurements as well as superimpositions of the models manufactured from the two procedures showed no significant differences between the digital models and the plaster casts.[6,25]

When measurements from the digital models and the plaster casts were compared with the intraoral measurements, statistically significant differences were found between the intraoral measurements and both the plaster casts and the digital models. It has previously been proposed that neither of the procedures provides an exact intraoral replica of teeth and surrounding tissue.[6] This was supported by the results of the present study. As only the maxillary arch was measured, the results are applicable solely for this arch. Also, it should be considered that intraoral measurements may be subject to interference especially in children, which may make it difficult to obtain accurate measurements.

Costs

In the present study, the initial price of digital models highly exceeded the price of plaster casts until 3.6 years later when the cost of the two procedures was equalized. No replacement of the equipment was taken into consideration and only under these circumstances, the cumulative costs of plaster casts exceeded the costs of digital models after 3.6 years. One study previously looked into the costs regarding the two techniques[8] and found that an intraoral scanner could pay for itself within two years. Other studies have avoided commenting on the cost, most likely due to the many different digital intraoral system configurations on the market, a fact that makes it difficult to generalize the costs.[26] In the present study, some limitations restrict the general applicability of the cost calculation: it was undertaken in a single center, using only one type of scanner and assuming a defined number of dental models per year. Costs for the two procedures

may be different between different countries but, as the assumption is the same for the two procedures, the relative proportion should be the same. The findings regarding cost in the present study may therefore prove valuable in various countries.

CONCLUSIONS

- Patient experience was statistically better during intraoral scan compared with alginate impression.
- No significant difference in chairside time was found between the two procedures.
- Dental arch distances on the digital models and plaster casts were significantly larger compared with the intraoral measurements, but no significant differences were found between digital models and plaster casts.
- The intraoral scanner technique was more expensive during the first 3.6 years, but less expensive than the alginate impression technique thereafter.
- The results may prove valuable for the decision and implementation of an intraoral scanner in orthodontic practice.

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