Original Article

Transfer accuracy of four different lingual retainer transfer methods using digital orthodontic models: *An in vivo comparative study*

Yasemin Nur Korkmaz[a]; Semiha Arslan[a]

ABSTRACT

Objectives: To compare the transfer accuracy of four different lingual retainer (LR) transfer methods using three-dimensional digital models.

Materials and Methods: Four groups of 17 patients each were created: finger transfer (FT), silicone key transfer (SKT), acrylic resin transfer (ART), and indirect bonding (IDB). At the end of orthodontic treatment, the mandibular dental casts of patients were scanned with the LR wire. Then, intraoral scanning of the mandibular arches was performed after bonding the retainer wires. Linear and angular measurements were made using software on superimposed digital models.

Results: Horizontal and vertical errors among the teeth were not significantly different among the FT, SKT, and ART groups. However, in the IDB group, linear transfer errors showed significant differences among the different teeth. The tip and rotation errors in the FT group were not significantly different among the teeth. The angular errors were lower in canines than in the incisors. In all measured parameters, the SKT group showed the lowest errors, whereas the FT group had the highest transfer errors in all parameters except vertical.

Conclusions: Among the transfer methods tested, SKT was determined to have the highest clinical accuracy. (*Angle Orthod.* 2021;91:778–785.)

KEY WORDS: Acrylic resin; Indirect bonding; Intraoral scanner; Lingual retainer; Silicone

INTRODUCTION

The application of a lingual retainer (LR) requires precision, and errors such as inadequate adaptation of the wire and saliva contamination of the etched surfaces may cause undesirable consequences during retention. Inadvertent tooth movement may occur for various reasons, such as incorrect positioning of the LR wire while bonding it to the teeth.[1–3] In addition, application requires extended chair time and may result in bond failure or wire breaks.[4] To facilitate the application of an LR, different techniques have been introduced.

Bonding techniques of the LR may be divided into two basic categories: direct and indirect. As the perfect fit of the wire to the lingual surfaces of the teeth must be ensured, the use of dental floss[5–8] and ligature wire and orthodontic elastics[8–10] has been suggested to hold the bent wire in place during bonding. In addition, different carrier materials such as resin and silicone or fingers can be used for both the transfer and placement of the wire in the direct technique.[8,11–13]

The use of orthodontic scanners is becoming widespread and three-dimensional (3D) orthodontic models are rapidly replacing plaster models. Digital models have the advantage of being easy to access, reproduce, and communicate along with reduced physical storage space.[14,15] The accuracy, reliability, and effectiveness of measurements from digital models have been found to be similar to plaster models and they may therefore be used as an alternative.[16]

The purpose of this study was to compare the transfer accuracy of four different direct (fingers, silicone, acrylic) and indirect LR transfer methods using digital patient records obtained by an intraoral digital scanner (IDS).

[a] Assistant Professor, Department of Orthodontics, Faculty of Dentistry, Bolu Abant Izzet Baysal University, Bolu, Turkey.

Corresponding author: Dr Semiha Arslan, Department of Orthodontics, Faculty of Dentistry, Bolu Abant İzzet Baysal University, 14030 Bolu, Turkey
(e-mail: semmarslan@gmail.com)

Accepted: May 2021. Submitted: February 2021.
Published Online: July 21, 2021

Figure 1. Silicone key transfer (SKT) preparation and application.

MATERIALS AND METHODS

This project was approved by the Clinical Research Ethical Committee of Bolu Abant İzzet Baysal University. Informed consent was obtained from the parents and patients. Four groups were identified as finger transfer (FT; 17 patients; 10 girls, 7 boys; mean age 18.11 ± 2.47 years), silicone key transfer (SKT; 17 patients; 9 girls, 8 boys; mean age 19.58 ± 3.35 years), acrylic resin transfer (ART; 17 patients; 10 girls, 7 boys; mean age 18 ± 2.71 years), and indirect bonding (IDB; 17 patients; 8 girls, 9 boys; mean age 18.25 ± 3.02 years). Sample size was determined based on a power analysis using G*Power software version 3.1.9.2 (Universitat Dusseldorf, Germany) at alpha error probability of 0.05, effect size of 0.42, and a power of 80%. Systemically healthy patients with no decayed, missing, or restored mandibular teeth, no periodontal problems, and no previous orthodontic treatment were included. At the end of the nonextraction active treatment, debonding procedures were completed and impressions were taken using Orthoprint (Zhermack S.p.A., Badia Polesine, Rovigo, Italy) alginate in the mandible of patients. Plaster models were made using Elite Ortho (Zhermack S.p.A.) type 3 dental stone. All LRs were prepared on the models by the same laboratory technician from first premolar to first premolar using 0.0175-inch six-stranded stainless steel wire (Ortho Technology, Lutz, Fla). The retainer wires were fixed on the plaster models using orthodontic wax on the occlusal surfaces of the first premolars. Then, the plaster models were scanned using the 3Shape Trios-3 (3Shape, Copenhagen, Denmark) IDS. The digital plaster model scans (DPMS) were stored in a computer by the 3Shape OrthoAnalyzer software (3Shape, Copenhagen, Denmark).

In all groups, the teeth were cleaned and polished and then etched with 32% orthophosphoric acid (3M Unitek, Monrovia, Calif) for 20 seconds. Teeth were washed and dried, and Transbond XT Light Cure Adhesive Primer (3MUnitek) was applied. Transbond LR Light Cure Adhesive (3MUnitek) was used to bond the retainer wires. All retainers were bonded by the same experienced orthodontist according to the manufacturer's instructions.

In the FT group, the final retainer wire on the plaster model was transferred and passively adapted to the optimal position on the mandibular teeth using fingers. No other transfer material was used. The retainer wire was bonded to each tooth starting from the left first premolar and moving toward the right first premolar.

In the SKT group, a silicone key was prepared for each plaster model on which the retainer wire was adapted. A silicone key was placed on the mandibular central incisors to hold the retainer wire in the correct position.[4] The retainer wire was transferred and placed on the mandibular teeth along with the silicone key. After bonding the wire to the first premolars and canines, the silicone key was removed, and bonding of the remaining teeth was completed (Figure 1).

In the ART group, the retainer wire was held using orthodontic acrylic resin (Orthocryl, Ispringen, Germany) on the occlusal surfaces of the first premolar teeth.[13] The transfer and placement of the wire from the plaster model to the mandibular teeth were guided by the acrylic resin cap. The wire was initially bonded on the mandibular incisors and canines and the acrylic resin cap was then removed. The retainer was then bonded to the mesioocclusal surfaces of the first premolar teeth (Figure 2).

In the IDB group, the model was isolated using an insulating fluid. The retainer wire was fixed using wax on the occlusal surfaces of the first premolars. Transbond LR Light Cure Adhesive was applied to the lingual surfaces of the mandibular teeth and was cured for 3 seconds with VALO Ortho (Ultradent Products, South Jordan, Utah) for each tooth. A double-vacuum form tray (soft and hard with a thickness of 1 mm each; Dentsply Raintree Essix, Sarasota, Fla) was prepared

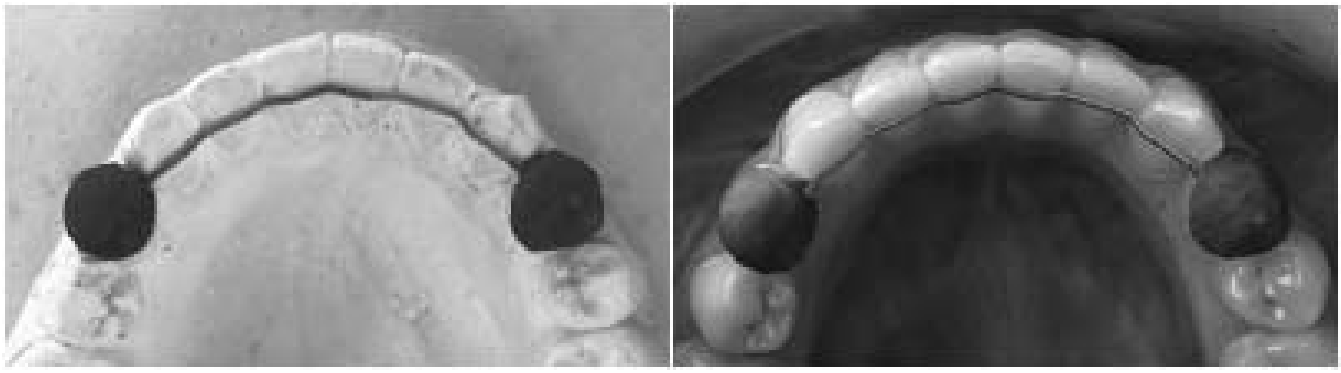

Figure 2. Acrylic resin transfer (ART) preparation and application.

for the transfer and placement of the wire using a pressure molding machine (Cavex VacuFormer System, Haarlem, The Netherlands)[17] and was cut at the edges of the lingual and facial surfaces of the teeth. After the removal of the transfer tray with the retainer wire from the plaster model, 90-μm aluminum oxide was used for microetching the adhesive. Transbond LR Light Cure Adhesive was applied as a thin layer to the lingual surfaces of the mandibular teeth and the inner surface of the double-vacuum form tray.[4] The tray was then placed on the teeth (Figure 3). After polymerization was completed, the double-vacuum form tray was removed.

After bonding the retainers, the mandibular arches of all patients were scanned using the 3Shape Trios 3 IDS. The patient digital intraoral scans (PDIS) were stored in a computer by the 3Shape Ortho Analyzer software.

DPMS and PDIS were superimposed using GOM Inspect Software 2019 (GOM GmbH, Braunschweig, Germany)[17] DPMS and PDIS were superimposed using the mesiobuccal cusps of the mandibular right and left first molar teeth and the incisal middle of the mandibular central incisors by ensuring the highest overlap in the heat map. Four points per tooth were determined: two on the mesial and two on the distal sides, along the LR wire. The points were marked at the middle of the two adjacent teeth as the peaks of the LR wire on the occlusal and lingual sides (Figures 4 and 5). Tip and rotation calculations were made. Negative measurements indicated a more exposed PDIS, and positive measurements indicated a more exposed DPMS. All 68 LR wires were bonded successfully, and measurements were carried out on digital models by the same experienced orthodontist who was blinded to the groups. Twenty days after the initial evaluation, the same observer reevaluated the 3D models for evaluation of intraobserver reliability.

Statistical Analysis

Measurements were compared among teeth in each group using Kruskal-Wallis and one-way analysis of variance (ANOVA). Post hoc comparisons were conducted using the Mann-Whitney *U* test with Bonferroni correction after the Kruskal-Wallis test and Tukey test following one-way ANOVA. The Kruskal-Wallis test was used to compare the transfer errors among the four methods. Mann-Whitney *U* tests were used for pairwise comparisons, and the Bonferroni correction was applied. Intraclass correlation coefficient (ICC) was calculated to assess intraobserver reliability. Statistical analyses were conducted using

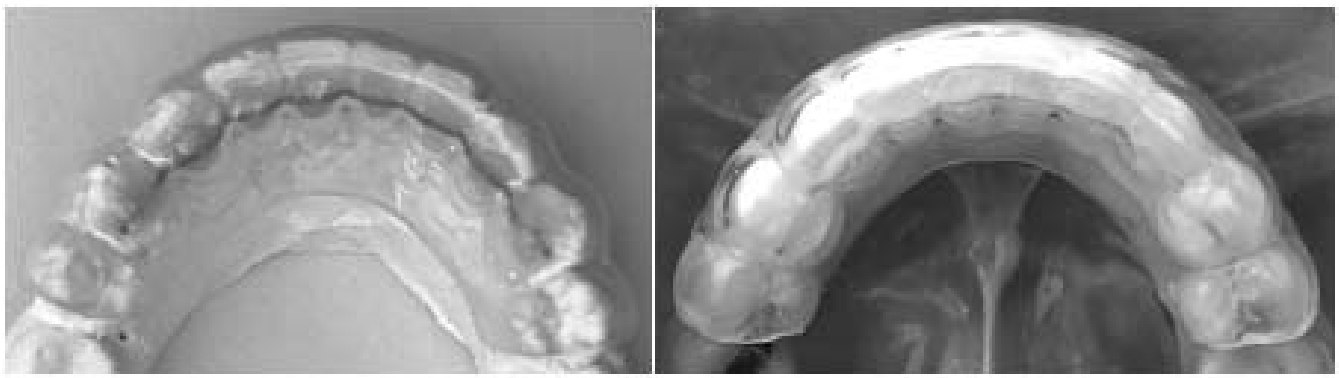

Figure 3. Indirect bonding (IDB) preparation and application.

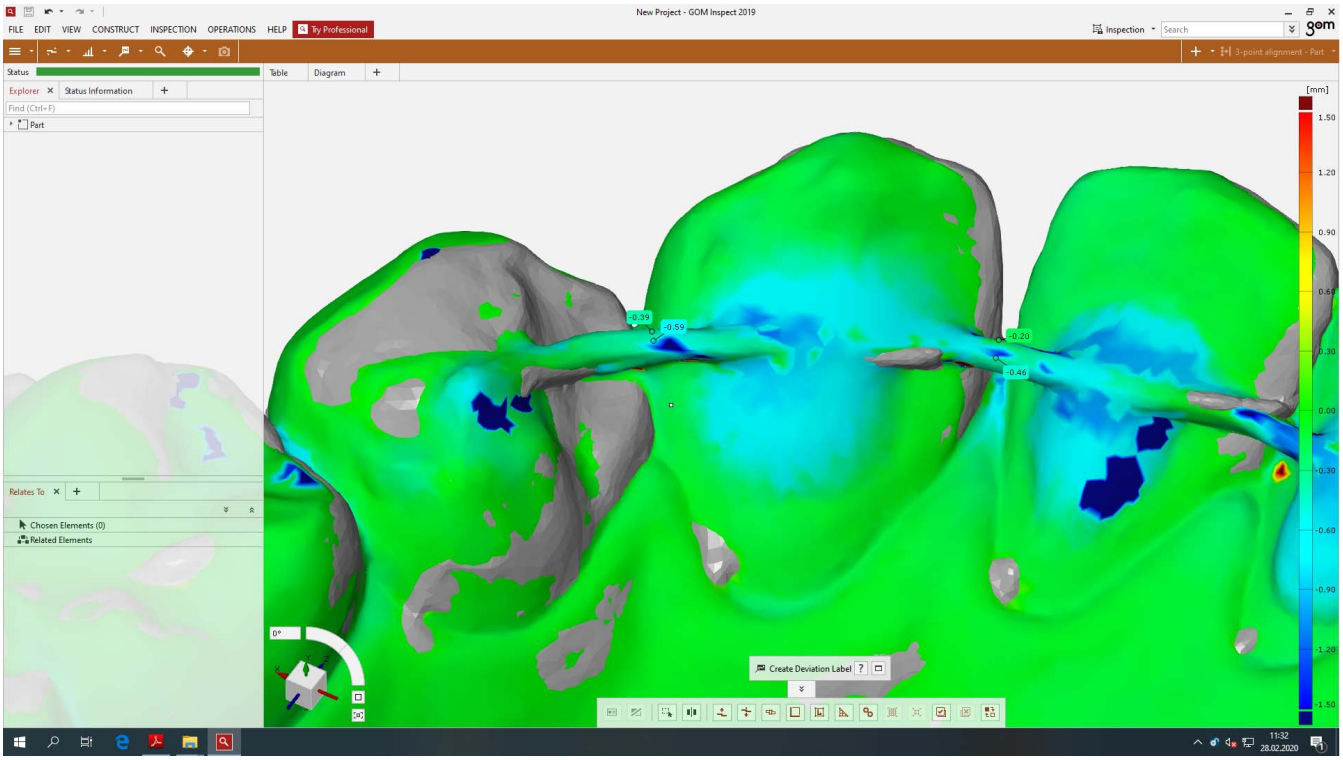

Figure 4. Lingual view of measurement points.

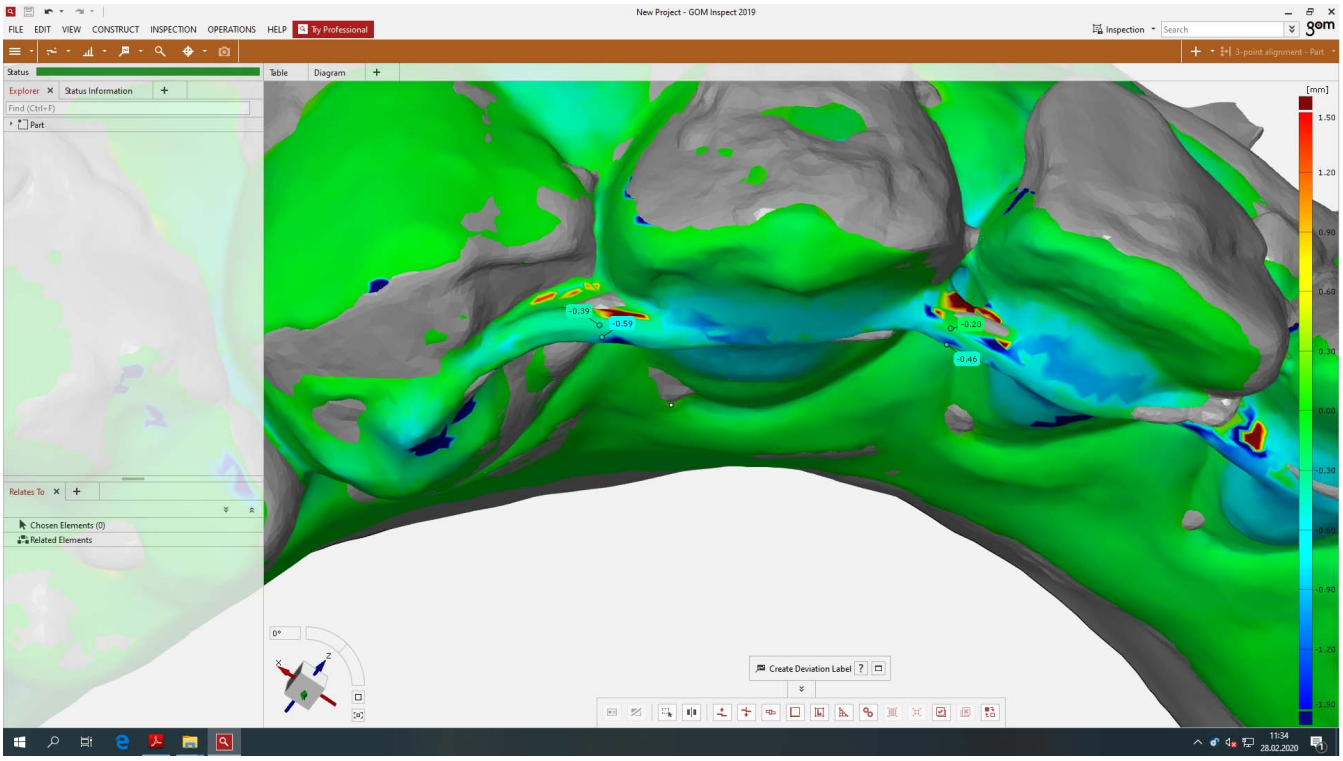

Figure 5. Occlusal view of measurement points.

Table 1. Comparison of Linear Transfer Errors Among Different Teeth in Four Different Lingual Retainer Transfer Methods[a]

Transfer Method	Transfer Error	Tooth[b] (Mean ± SD)				
		44–43	43–42	42–41	41–31	31–32
FT	Horizontal, mm	−0.846 ± 0.440	−0.676 ± 0.611	−0.809 ± 0.274	−0.810 ± 0.188	−0.803 ± 0.228
	Vertical, mm	−0.616 ± 1.084	−0.397 ± 0.904	−0.578 ± 0.902	−0.216 ± 1.195	−0.162 ± 0.980
SKT	Horizontal, mm	−0.323 ± 0.288	−0.236 ± 0.328	−0.291 ± 0.226	−0.207 ± 0.270	−0.222 ± 0.308
	Vertical, mm	−0.214 ± 0.319	−0.175 ± 0.291	0.0165 ± 0.291	−0.0406 ± 0.333	−0.153 ± 0.253
ART	Horizontal, mm	−0.508 ± 0.295	−0.488 ± 0.238	−0.441 ± 0.222	−0.317 ± 0.281	−0.425 ± 0.295
	Vertical, mm	−0.346 ± 0.370	−0.355 ± 0.413	−0.281 ± 0.387	−0.212 ± 0.282	−0.269 ± 0.390
IDB	Horizontal, mm	−0.349 ± 0.307	−0.303 ± 0.263	−0.295 ± 0.357	−0.559 ± 0.361	−0.504 ± 0.295
	Vertical, mm	−0.285 ± 0.409	−0.231 ± 0.290	−0.374 ± 0.403	−0.546 ± 0.522	−0.489 ± 0.432

[a] ART indicates acrylic resin transfer; FT, finger transfer; IDB, indirect bonding; SKT, silicone key transfer.
[b] (–) indicates the measurement at the contact point between the numbered teeth.
[c] Kruskal-Wallis test.
[d] One-way ANOVA test.
[e] Tukey test.
[f] Bonferroni-corrected Mann-Whitney *U* test.

SPSS version 20.0 (SPSS Inc, Chicago, Ill). The level of statistical significance was set at $P < .05$.

RESULTS

The intraobserver reliability was found to be good, with an ICC of >.774.

Table 1 displays the intragroup comparisons of linear transfer errors. The horizontal and vertical errors among teeth were not significantly different in the FT, SKT, and ART groups. In the IDB group, however, linear transfer errors showed significant differences among the teeth. The vertical transfer error was significantly lower in the wire at the contact point of 33–34 than at 43–42, showing that the retainer wire at the contact point between 33–34 was more exposed in PDIS.

The intragroup comparisons of angular transfer errors are shown in Table 2. The tip and rotation errors in the FT group were not significantly different among teeth. The rotational error of tooth 42 was significantly greater than that of 43 and 33 in the SKT group, while it was significantly greater on tooth 41 than on 43 and 33 in the ART and IDB groups. In the ART group, the tip error of tooth 33 was significantly lower than that of teeth 42, 32, and 41. Although not significant, it was observed that the values of the angular errors were lower on the canines than on the incisors. This indicated that the angular errors were higher in the middle part of the wire.

The results of the intergroup comparisons are displayed in Table 3, in which the data were obtained by combining the data belonging to every individual tooth for each measurement. The four measured parameters were significantly different among the transfer methods. In all parameters, the SKT group showed the lowest errors, while the FT group had the highest transfer errors in all parameters except vertical. Post hoc comparisons showed that all of the measured errors except for the tip were significantly lower in the SKT group than in the other three groups, and the tip error of the SKT group was also significantly lower than that of the FT group.

DISCUSSION

Different studies in the literature have compared direct and indirect methods of LR transfer in terms of failure rate, posttreatment changes, and placement time.[4,18] The accuracy of bracket placement between the direct and IDB techniques and between the different IDB techniques has also been compared.[17,19,20] However, this is the first study to compare the transfer success of different LR transfer methods using 3D models.

The use of IDS has been shown to be valid, reliable, and reproducible for dental measurements.[21–24] The 3Shape Trios IDS was used in this study, as it was previously found to have the best sensitivity[25] and a balance of speed and accuracy.[26]

In the intragroup comparisons of the transfer errors, the linear transfer error between different teeth was not significant in the FT, SKT, and ART groups. However, the difference was significant in the IDB group. The wire between teeth 33–34 moved significantly more occlusal than the wire between teeth 42–43. This may have been caused by the way the operator placed the IDB tray. The operator placed the tray starting from the right side of the mouth since she was right-handed.

Angular transfer errors did not differ significantly between teeth in the FT group, while they were significantly different in the SKT, ART, and IDB groups. The reason that there was no angular difference between the teeth in the FT group may be attributed to the fact that the LR was bonded to the teeth individually with the help of a finger in this group.

Table 1. Extended

Tooth[b] (Mean ± SD)			
32–33	33–34	*P*	Post hoc *P*
−0.851 ± 0.408	−0.806 ± 0.397	.930[c]	—
−0.240 ± 0.947	−0.494 ± 0.761	.641[c]	—
−0.210 ± 0.253	−0.219 ± 0.258	.796[c]	—
−0.184 ± 0.255	−0.146 ± 0.242	.146[c]	—
−0.389 ± 0.283	−0.424 ± 0.232	.440[c]	—
−0.394 ± 0.350	−0.396 ± 0.322	.580[c]	—
−0.452 ± 0.271	−0.554 ± 0.266	.032[d]	42–41/41–31: $P = .162$[e]
−0.565 ± 0.293	−0.618 ± 0.271	.004[c]	43–42/33–34: $P = .009$[f]

However, in the SKT and ART groups, premolar and canine teeth were bonded first; the transfer attachments were then removed, and the incisors were then bonded. Because the incisors were bonded in the final stage, this may have caused the angular error in the middle part of the LR wire to be higher than the ends of the wire. Similar results in the IDB group might be attributed to the way the Essix plate was placed.

When the four different methods were compared, the SKT group showed significantly lower errors in all measurements. It was the most effective and error-free method among the methods tested. Since the silicone key was located on the central incisors, it did not cover all the teeth, and it was easy to place it on the teeth and remove it after the wire was bonded. Clinically, it was also observed that the operator worked more comfortably with the SKT method. In the laboratory stage, it

Table 2. Comparison of Angular Transfer Errors Among Different Teeth in Four Different LR Transfer Methods[a]

Transfer Method	Transfer Error	Tooth (Mean ± SD)							
		43	42	41	31	32	33	*P*	Post hoc *P*
FT	Tip, °	2.484 ± 1.049	2.900 ± 2.055	3.538 ± 4.773	2.351 ± 1.110	3.091 ± 1.876	3.237 ± 2.239	.955[b]	—
	Rotation, °	1.912 ± 1.491	2.184 ± 1.457	2.643 ± 1.846	2.354 ± 1.872	2.754 ± 1.820	1.506 ± 1.116	.201[b]	—
SKT	Tip, °	0.727 ± 0.996	2.082 ± 2.995	2.590 ± 1.946	1.726 ± 1.817	3.167 ± 4.546	0.724 ± 1.277	.034[c]	32/33: $P = .069$[d]
	Rotation, °	0.638 ± 1.105	1.365 ± 0.980	1.355 ± 1.813	1.040 ± 1.269	1.166 ± 1.702	0.345 ± 0.288	.003[b]	42/43: $P = .015$[e]
									42/33: $P = .017$[e]
ART	Tip, °	1.560 ± 2.289	3.196 ± 2.108	2.864 ± 2.809	2.219 ± 2.378	2.735 ± 2.878	0.421 ± 0.399	<.001[b]	42/33: $P < 0.001$[e]
									32/33: $P = .029$[e]
									41/33: $P = .031$[e]
	Rotation, °	0.835 ± 1.295	2.353 ± 2.001	2.887 ± 2.684	1.572 ± 2.458	2.147 ± 2.091	0.681 ± 0.610	<.001[b]	41/43: $P = .007$[e]
									41/33: $P = .018$[e]
IDB	Tip, °	1.291 ± 1.122	2.910 ± 2.124	2.198 ± 2.560	2.574 ± 1.856	2.894 ± 2.456	1.081 ± 0.960	.088[b]	—
	Rotation, °	0.858 ± 0.617	2.041 ± 1.729	3.198 ± 2.180	2.175 ± 1.892	1.493 ± 1.693	0.869 ± 0.657	<.001[b]	41/43: $P = .006$[e]
									41/33: $P = .008$[e]

[a] ART indicates acrylic resin transfer; FT, finger transfer; IDB, indirect bonding; SKT: silicone key transfer.
[b] Kruskal-Wallis test.
[c] One-way ANOVA test.
[d] Tukey test.
[e] Bonferroni-corrected Mann–Whitney *U* test.

Table 3. Significance of Differences Between Four Different LR Transfer Methods[a]

Transfer Error	Transfer Method				*P*[b]	Post hoc *P*[c]
	FT	SKT	ART	IDB		
Horizontal, mm	−0.800 ± 0.382	−0.244 ± 0.274	−0.427 ± 0.265	−0.431 ± 0.316	<.001	FT/SKT: $P < .001$
						FT/ART: $P < .001$
						FT/IDB: $P < .001$
						ART/SKT: $P < .001$
						IDB/SKT: $P < .001$
Vertical, mm	−0.386 ± 0.966	−0.128 ± 0.289	−0.322 ± 0.358	−0.444 ± 0.399	<.001	FT/SKT: $P < .001$
						ART/SKT: $P < .001$
						IDB/SKT: $P < .001$
Tip, °	2.934 ± 2.484	1.836 ± 2.656	2.166 ± 2.430	2.158 ± 2.034	<.001	FT/SKT: $P < .001$
						FT/ART: $P < .001$
						FT/IDB: $P = .006$
Rotation, °	2.226 ± 1.639	0.985 ± 1.318	1.746 ± 2.096	1.772 ± 1.746	<.001	FT/SKT: $P < .001$
						FT/ART: $P < .001$
						FT/IDB: $P = .025$
						ART/SKT: $P = .014$
						IDB/SKT: $P < .001$

[a] ART indicates acrylic resin transfer; FT, finger transfer; IDB, indirect bonding; SKT, silicone key transfer.
[b] Kruskal-Wallis test.
[c] Bonferroni-corrected Mann-Whitney *U* test.

was easier to insert the silicone key. Schmid et al.[17] evaluated two different indirect transfer methods for bracket bonding and showed that the SKT method gave better results than the IDB method with double-vacuum forms. The result was similar to the current study. Castilla et al.,[20] compared the bracket transfer accuracy of five IDB methods and found that the transfer method with silicone-based trays was more accurate than the transfer method with the vacuum-formed trays. The current results were also similar.

The FT group showed significantly more transfer errors than the other groups, and this might have been due to the absence of a transport guide when the operator placed the wire with her fingers. It could be said that the FT method required less laboratory time as compared with the other three transfer methods, since it did not require additional processing other than the LR wire bending. In clinical practice, however, the operator experienced that the LR wire in the FT group was more difficult to place and attach to the teeth since there was no transfer material.

The transfer errors of the ART and IDB methods were similar to each other. In the ART method, it was thought that the placement of acrylic resin on the premolar teeth decreased the transfer success as compared with the SKT method. In the IDB method, the operator observed difficulty in placing and removing the Essix plate. This could be the reason that the transfer success was lower in the IDB group than with the SKT method. The transfer tray was more difficult to remove after bonding since the retainer wire was embedded in the tray due to its lower volume in comparison with when this method is used to bond brackets.

Complications may occur due to errors in the transfer of the mandibular LR or passive placement of the wire.[1,2] Forming the LR wire on the plaster model to be passive and using a transfer tray to prevent errors that may occur due to finger pressure is effective for preventing complications that may occur,[27] which emphasizes the importance of the LR transfer method.

A relatively new digital method for retention, using Memotain, is a computer-aided design/computer-aided manufacturing (CAD/CAM)–produced retainer using custom-cut nickel-titanium wire with the advantages of precise fit, interference avoidance, and corrosion resistance.[28] With the inevitable development of new technology, the production of similar retainer wires will increase; therefore, in future studies, the transfer accuracy of CAD/CAM–produced retainer wires should be evaluated.

The limitation of this study was the possible distortion of the plaster models and alginate impressions. Minor distortions might have occurred during the fabrication of the plaster models, which could have resulted in minor measurement errors. To minimize the distortion, the materials were used according to the manufacturer's instructions. In addition, the models were obtained after debonding the brackets since the presence of the brackets on the labial surface could increase distortion.

CONCLUSIONS

- Among the four different LR transfer methods tested in the present study, SKT was the method with the highest clinical accuracy.
- Transporting and placing LRs with the aid of a silicone key, acrylic resin, or an Essix tray was more accurate than using only fingers.

REFERENCES

1. Pazera P, Fudalej P, Katsaros C. Severe complication of a bonded mandibular lingual retainer. *Am J Orthod Dentofac Orthop*. 2012;142:406–409.
2. Katsaros C, Livas C, Renkema AM. Unexpected complications of bonded mandibular lingual retainers. *Am J Orthod Dentofac Orthop*. 2007;132:838–841.
3. Shaughnessy TG, Proffit WR, Samara SA. Inadvertent tooth movement with fixed lingual retainers. *Am J Orthod Dentofac Orthop*. 2016;149:277–286.
4. Bovali E, Kiliaridis S, Cornelis MA. Indirect vs direct bonding of mandibular fixed retainers in orthodontic patients: a single-center randomized controlled trial comparing placement time and failure over a 6-month period. *Am J Orthod Dentofac Orthop*. 2014;146:701–708.
5. Zachrisson B. The bonded lingual retainer and multiple spacing of anterior teeth. *J Clin Orthod*. 1983;17:838–846.
6. Orsborn DB. Bonded lingual retainers. *Am J Orthod*. 1983; 83:218–220.
7. Paulson RC. A functional rationale for routine maxillary bonded retention. *Angle Orthod*. 1992;62:223–226.
8. Zachrisson BU. Clinical experience with direct-bonded orthodontic retainers. *Am J Orthod Dentofac Orthop*. 1977; 71:440–448.
9. Meyers C Jr, Vogel S. Stabilization of retainer wire for direct bonding. *J Clin Orthod*. 1982;16:412.
10. Wasuita M. Simplified technique for mandibular bonded retainers. *J Clin Orthod*. 1982;16:182.
11. Eade P. A modified direct bond lingual retainer technique. *Br J Orthod*. 1980;7:125–126.
12. Hobson R, Eastaugh D. Silicone putty splint for rapid placement of direct-bonded retainers. *J Clin Orthod*. 1993; 27:536.
13. Lee SJ, Ihm JA, Ahn SJ. Time-saving fixed lingual retainer using DuraLay resin transfer. *Am J Orthod Dentofac Orthop*. 2004;125:203–205.
14. Marcel TJ. Three-dimensional on-screen virtual models. *Am J Orthod Dentofac Orthop*. 2001;119:666–668.
15. Santoro M, Galkin S, Teredesai M, Nicolay OF, Cangialosi TJ. Comparison of measurements made on digital and plaster models. *Am J Orthod Dentofac Orthop*. 2003;124: 101–105.

16. Quimby ML, Vig KW, Rashid RG, Firestone AR. The accuracy and reliability of measurements made on computer-based digital models. *Angle Orthod*. 2004;74:298–303.
17. Schmid J, Brenner D, Recheis W, Hofer-Picout P, Brenner M, Crismani AG. Transfer accuracy of two indirect bonding techniques—an in vitro study with 3D scanned models. *Eur J Orthod*. 2018;40:549–555.
18. Egli F, Bovali E, Kiliaridis S, Cornelis MA. Indirect vs direct bonding of mandibular fixed retainers in orthodontic patients: comparison of retainer failures and posttreatment stability. A 2-year follow-up of a single-center randomized controlled trial. *Am J Orthod Dentofac Orthop*. 2017;151:15–27.
19. Koo BC, Chung CH, Vanarsdall RL. Comparison of the accuracy of bracket placement between direct and indirect bonding techniques. *Am J Orthod Dentofac Orthop*. 1999; 116:346–351.
20. Castilla AE, Crowe JJ, Moses JR, Wang M, Ferracane JL, Covell DA Jr. Measurement and comparison of bracket transfer accuracy of five indirect bonding techniques. *Angle Orthod*. 2014;84:607–614.
21. Cuperus AMR, Harms MC, Rangel FA, Bronkhorst EM, Schols JG, Breuning KH. Dental models made with an intraoral scanner: a validation study. *Am J Orthod Dentofac Orthop*. 2012;142:308–313.
22. Flügge TV, Schlager S, Nelson K, Nahles S, Metzger MC. Precision of intraoral digital dental impressions with iTero and extraoral digitization with the iTero and a model scanner. *Am J Orthod Dentofac Orthop*. 2013;144:471–478.
23. Naidu D, Freer TJ. Validity, reliability, and reproducibility of the iOC intraoral scanner: a comparison of tooth widths and Bolton ratios. *Am J Orthod Dentofac Orthop*. 2013;144:304–310.
24. Wiranto MG, Engelbrecht WP, Nolthenius HET, van der Meer WJ, Ren Y. Validity, reliability, and reproducibility of linear measurements on digital models obtained from intraoral and cone-beam computed tomography scans of alginate impressions. *Am J Orthod Dentofac Orthop*. 2013; 143:140–147.
25. Anh JW, Park JM, Chun YS, Kim M, Kim M. A comparison of the precision of three-dimensional images acquired by 2 digital intraoral scanners: effects of tooth irregularity and scanning direction. *Korean J Orthod*. 2016;46:3–12.
26. Renne W, Ludlow M, Fryml J, et al. Evaluation of the accuracy of 7 digital scanners: an in vitro analysis based on 3-dimensional comparisons. *J Prosthet Dent*. 2017;118:36–42.
27. Kim TK, Baek SH. Lingual bonded retainers: a case series of complications and resolutions. *APOS Trends Orthod*. 2020; 10:3–11.
28. Kravitz ND, Grauer D, Schumacher P, Jo YM. Memotain: a CAD/CAM nickel-titanium lingual retainer. *Am J Orthod Dentofac Orthop*. 2017;151:812–815.