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Effect of Closed-Tray Impression Coping Design on the Dimensional Accuracy of Implant Definitive Casts: An In Vitro Study

Gamzenur Çiçek
Bezmiâlem Vakıf Üniversitesi
Melih ÜLGEY
melihulgey@gmail.com

Burdur Mehmet Akif Ersoy Üniversitesi

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Additional Declarations: Competing interest reported. The coping used as the control (MomentDent; ESTAŞ Medikal A.Ş.) is a commercially available product of the same manufacturer. The 4 experimental designs were developed as candidate improvements on this existing product, and their design and manufacture were carried out by ESTAŞ Eksantrik Sanayi ve Ticaret A.Ş., which also provided the impression copings and implant analogs free of charge. The impressions, cast fabrication, and all measurements were performed independently in the research laboratory of Sivas Cumhuriyet University by an operator blinded to group allocation. The authors declare no other competing interests.

Abstract

Background

To compare the dimensional accuracy of implant definitive casts produced with five closed-tray impression coping designs differing in outline form and extent of retentive grooving.

Methods

Five closed-tray coping designs were evaluated: a commercially available coping (CTRL) and four experimental designs, square or tapered, each with limited or extensive grooving (SQ-L, SQ-E, TP-L, TP-E). The experimental designs were machined from Ti-6Al-4V ELI and the control was obtained from commercial stock; all copings were 13 mm in length, and the tapered designs had convergence angles of 2.15° (TP-L) and 2.86° (TP-E). Five implant analogs (A–E) were placed in parallel prepared sites in an edentulous maxillary acrylic resin master model, and six impressions per group (n = 6) were made by a single operator using a standardized perforated custom tray and single-step polyvinyl siloxane. Casts were poured in Type IV stone and digitized with the master model using an optical scanner. Absolute deviations from the master model were analyzed for three outcomes: the mean absolute reference-to-analog deviation, two transverse-plane distances (A–E, B–D), and the mean sagittal-plane deviation (1-way or Welch ANOVA, $P < 0.05$).

Results

Coping design significantly affected the mean absolute reference-to-analog deviation ($P < 0.001$): CTRL showed the greatest deviation (330.4 ± 24.5 μm) and differed from all experimental designs, and SQ-E (281.8 ± 21.6 μm) deviated more than SQ-L (208.3 ± 12.7 μm) and TP-E (201.5 ± 37.6 μm). The ranking was the same in the sagittal plane ($P < 0.001$), where CTRL (240.0 ± 50.4 μm) and SQ-E (230.3 ± 25.9 μm) deviated more than the remaining designs. Neither transverse-plane measurement differed among groups (A–E, $P = 0.051$; B–D, $P = 0.627$).

Conclusions

Closed-tray coping design affected the dimensional accuracy of definitive casts, and the commercially available coping was the least accurate design tested. A tapered outline form or limited retentive grooving should be preferred, since extending the grooving impaired rather than improved accuracy.

BACKGROUND

Implant-supported restorations have become a routine treatment for partial and complete edentulism, and their survival rates have been well documented over follow-up periods exceeding 5 years [1–2]. Once

the implants have been placed in alveolar bone, the prosthetic phase begins, and the accuracy with which their intraoral positions are transferred to the definitive cast is critical to the fit of the final restoration. Because the implant-abutment complex is rigid and lacks the compensatory mobility provided by the periodontal ligament, transfer errors cannot be accommodated and are instead expressed directly at the implant-prosthesis interface [3–5].

Failure to reproduce the 3-dimensional implant positions on the definitive cast compromises passive fit and has been associated with screw loosening, abutment or implant fracture, and prosthetic failure. The resulting marginal discrepancy may also promote plaque accumulation and adverse peri-implant tissue responses [6–7]. Implant impressions can be made with either an open-tray (pick-up) or closed-tray (transfer) technique. Although the open-tray technique is generally preferred for deeply placed or markedly divergent implants, limited interarch space, difficult posterior access, or a pronounced gag reflex may make the closed-tray approach the only practical option [8].

In the closed-tray technique, the impression coping is removed from the implant after polymerization and manually repositioned into its corresponding recess in the impression. Accuracy therefore depends strongly on coping macrogeometry, which must retain the repositioned coping, guide accurate seating, and resist displacement during cast pouring. Manufacturers offer impression copings with various external contours, but no single geometry has been established as optimal [9]. Tapered copings with convergent axial walls are generally preferred for closed-tray impressions because they impose less strain on the impression material during impression removal and coping reinsertion [10]. Conversely, square copings with parallel walls may provide greater resistance to rotational and axial displacement [11–13].

Deeper surface undercuts may increase retention of the repositioned coping within the elastomer but may also deform the impression material during removal [9]. Various coping modifications, including acrylic resin extensions, adhesive coatings, and airborne-particle abrasion, have therefore been proposed to limit analog displacement and improve cast accuracy [14–16].

The purpose of this in vitro study was to compare the dimensional accuracy of definitive implant casts produced using 5 closed-tray impression coping designs that differed in external contour and in the extent and arrangement of their retentive surface features. The null hypothesis was that impression coping design would not affect the dimensional accuracy of the resulting casts.

MATERIAL AND METHODS

The design and manufacture of the experimental impression copings were carried out in the research and development unit of the manufacturer (MomentDent, ESTAŞ Medikal, Türkiye), whereas the impressions, cast fabrication, digitization, and all linear measurements were performed in the research laboratory of the Faculty of Dentistry, Sivas Cumhuriyet University.

Impression coping design and fabrication

Five closed-tray impression coping designs were evaluated (Table 1; Fig. 1). All impression copings and implant analogs were components of the same implant system, which had a conical connection and an internal hexagonal antirotational feature (MomentDent, ESTAŞ Medikal, Türkiye). The commercially available closed-tray coping served as the control (CTRL). Four experimental designs were also tested: square profile with limited grooving (SQ-L), square profile with extensive grooving (SQ-E), tapered profile with limited grooving (TP-L), and tapered profile with extensive grooving (TP-E). The experimental copings were designed with computer-aided design software (SolidWorks, Dassault Systèmes, France), standardized to the length of the commercial coping (13 mm), and varied in external profile and in the extent, arrangement, and orientation of their retentive surface features (Fig. 1).

Table 1
Impression coping designs evaluated

Group	Outline form	Retentive surface features	Convergence angle	Length
CTRL	Parallel (hexagonal flats)	2 shallow circumferential steps, middle third	0 degrees	13 mm
SQ-L	Parallel (square)	Shallow circumferential grooves, coronal third	0 degrees	13 mm
SQ-E	Parallel (square)	Deep rectangular indentations, alternating, over almost the entire length	0 degrees	13 mm
TP-L	Tapered	Fine vertical grooves only	2.15 degrees	13 mm
TP-E	Tapered	Rounded circumferential bulges and constrictions, coronal two-thirds	2.86 degrees	13 mm

CTRL, commercially available coping; SQ-L, square with limited grooving; SQ-E, square with extensive grooving; TP-L, tapered with limited grooving; TP-E, tapered with extensive grooving.

The experimental copings and implant analogs were machined from Ti-6Al-4V ELI on an 8-axis sliding-head computer numerical control lathe (B0326 E2, Tsugami Precision Works, Japan). TiAlN-coated tungsten carbide cutting tools and high-speed cutting oil with a kinematic viscosity of 9.2 mm^2/s were used, and burrs were removed mechanically. The CTRL copings were obtained from the manufacturer's commercial stock and were made from the same alloy. Five copings were used per group, one at each analog site.

Master model

An edentulous maxillary master model was fabricated from autopolymerizing acrylic resin (İntegra, Birleşik Grup Dental, Türkiye). Five analog sites were arranged symmetrically: one at the anterior midline, two in the premolar regions, and two in the molar regions. To ensure parallelism, the model was mounted

on a dental surveyor (M13FYM, Rotaks-Dent, Türkiye), and each site was prepared to a diameter of 2.5 mm and a depth of 5 mm with a 2.5-mm steel round bur (Hager & Meisinger, Germany) mounted in a handpiece (NSK-Nakanishi, Japan). Conical-connection implant analogs, 3.5 mm in diameter and with an internal hexagonal antirotational feature (MomentDent, ESTAŞ Medikal, Türkiye), were fixed in the prepared sites with the same acrylic resin. The analogs were designated A and E (molar), B and D (premolar), and C (anterior midline); analog A served as the fixed reference (Fig. 2).

Custom tray

A single custom tray was fabricated from the same autopolymerizing acrylic resin and used for all groups to standardize impression material thickness. A wax spacer approximately 4 mm thick was adapted over the master model, and an approximately 2-mm-thick layer of acrylic resin was applied over it. Custom trays have been reported to produce more accurate implant impressions than stock trays because they provide uniform support and more predictable retention of the impression material [17–18]. Because approximately 80% of the polymerization shrinkage of autopolymerizing acrylic resin occurs within the first 17 minutes after mixing and is complete by 24 hours, [19] the tray was separated from the model after 2 hours and was not used until at least 24 hours after fabrication. Retentive perforations were then prepared and the margins finished. No tray adhesive was applied; retention of the impression material was provided solely by the perforations.

Impression procedure

For each group, the corresponding five copings were connected to the analogs in the master model. A single experienced operator made all impressions with polyvinyl siloxane (Elite HD, Zhermack, Italy) using a simultaneous single-step heavy- and light-body technique. The heavy-body material was proportioned and mixed in an automatic mixing unit (Modulmix, Zhermack, Italy). To minimize void formation, light-body material was applied to the tray regions corresponding to the copings and distributed evenly with a cement spatula before tray placement. After polymerization, the tray was removed, the copings were disconnected from the master model, connected to laboratory analogs, and reseated in their corresponding locations in the impression. Six impressions were made per group (n = 6).

Cast fabrication

Because polyvinyl siloxane is dimensionally stable over extended storage periods, the impressions were stored for 24 hours under ambient laboratory conditions before pouring, which also allowed complete elastic recovery of the elastomer [20]. Type IV dental stone (Elite Rock, Zhermack, Italy) was proportioned and mixed at the manufacturer's recommended water/powder ratio of 20 mL/100 g and poured under vibration to minimize voids. The manufacturer-reported setting expansion was 0.08% after

2 hours. The casts were separated after complete setting, yielding 6 casts per group and 30 casts in total.

Digitization and measurement

At least 24 hours after cast fabrication, the master model and all 30 casts were coated with a thin, uniform layer of scanning spray (Dr.Mat White Scan Spray, Mat Kimya, Türkiye) to produce a homogeneous matte surface. They were digitized with a blue-light laboratory optical scanner (Camcube D15, Camcube, Canada) equipped with dual 2.0-megapixel cameras and a manufacturer-reported accuracy of 6 μm. The datasets were exported in standard tessellation language (STL) format and imported into computer-aided design software (dentalCAD, exocad, Germany) for linear measurements.

Two sets of linear measurements were recorded on the master model and each cast (Fig. 3). The first comprised four point-to-point distances from reference analog A to each of the remaining analogs: A→B, A→C, A→D, and A→E. The second comprised four measurements defined in the occlusal view. In the transverse plane (x-axis), the intermolar A–E distance between the centers of analogs A and E and the interpremolar B–D distance between the centers of analogs B and D were measured. In the sagittal plane (y-axis), the perpendicular distances from analogs B and D to the intermolar A–E line were measured and designated B⊥ and D⊥. Because these perpendicular distances were referenced to the A–E line, they represented the positions of B and D relative to the intermolar line rather than their absolute anteroposterior positions. Accordingly, B⊥ and A→B were distinct measurements and were analyzed and reported separately. The master model values are presented in Table 2.

Table 2
Measured distances and master model values

Outcome	Measurement set	Master model value (mm)	Plane
A→B	Reference-to-analog	18.373	—
A→C	Reference-to-analog	31.881	—
A→D	Reference-to-analog	40.403	—
A→E	Reference-to-analog	43.383	—
A–E	Intermolar distance	43.383	Transverse (x)
B–D	Interpremolar distance	33.149	Transverse (x)
B⊥	Perpendicular from analog B to the A–E line	12.369	Sagittal (y)
D⊥	Perpendicular from analog D to the A–E line	13.675	Sagittal (y)

Analog A served as the fixed reference for the reference-to-analog distances. B⊥ and D⊥ are the perpendiculars dropped from analogs B and D to the intermolar line passing through the centers of analogs A and E. The A→E reference-to-analog distance and the A–E transverse-plane measurement relate the same 2 terminal analogs but belong to separate measurement sets and are reported separately.

All measurements were made with the software distance tool by placing two points on the digitized surface. The software provided the three-dimensional distance between the points, its projection onto the active viewing plane, and the depth difference between the points. Measurement points were placed at the center of the visible analog platforms. The two measurement sets were acquired in separate sessions, with the points positioned independently in each session. Measurements were referenced to the analogs rather than to a fixed landmark on the model because relative interimplant measurements have been reported to more closely reflect clinical conditions. [21–22] All measurements were made once by a single operator who was blinded to group allocation.

Calculation of dimensional deviation

For each cast and each measured distance, the absolute dimensional deviation from the corresponding master model value was calculated as |dcast − dmaster|. The prespecified primary outcome, termed the mean absolute reference-to-analog deviation, was the arithmetic mean of the four absolute A-to-analog deviations and yielded one composite value per cast. This outcome represents the mean linear distance error and should not be interpreted as a three-dimensional displacement vector. Secondary outcomes were the absolute deviations of the two transverse measurements and the mean sagittal deviation, calculated as the mean of the absolute deviations of B⊥ and D⊥. The cast was the statistical unit (n = 6 per group); the four reference-to-analog deviations within a cast were averaged into a single composite

value rather than treated as independent replicates. Because all deviations were expressed as absolute values, the direction of error was not retained.

Statistical analysis

Data were analyzed with statistical software (SPSS 22.0, IBM Corp., Armonk, NY, USA), and graphs were prepared with graphing software (GraphPad Prism 8.0, GraphPad Software, USA). Normality was assessed with the Shapiro-Wilk test and homogeneity of variance with the Levene test. Intergroup comparisons were performed with 1-way ANOVA followed by the Tukey honestly significant difference test. For the mean absolute reference-to-analog deviation, which did not satisfy the homogeneity of variance assumption, Welch ANOVA with the Games-Howell post hoc test was used; the findings were also examined with conventional 1-way ANOVA and the Tukey test. For the A→B distance, which did not satisfy the normality assumption, the parametric result was confirmed with the Kruskal-Wallis test. Effect sizes were reported as eta squared (η^2) and omega squared (ω^2). No a priori sample size calculation was performed. For the nonsignificant transverse outcomes, a sensitivity analysis indicated that the minimum between-group differences detectable with 80% power were 88 μm for A–E and 54 μm for B–D. Values of $P < 0.05$ were considered statistically significant.

RESULTS

Data from the transverse and sagittal measurements met the assumptions of normality and homogeneity of variance. Because the homogeneity of variance assumption was not met for the mean absolute deviation in the reference-to-analog distances, Welch's ANOVA was used for this outcome. Mean dimensional deviations from the master model are presented in Table 3 and Figs. 4–7.

Table 3
Mean ±standard deviation of the absolute deviation from the master model by impression coping design and outcome (μm) (n = 6)

Group	Mean absolute reference-to-analog deviation	Transverse plane A–E	Transverse plane B–D	Mean sagittal plane deviation
CTRL	330.4 ± 24.5 [a]	250.2 ± 47.4 [a]	134.8 ± 46.5 [a]	240.0 ± 50.4 [a]
SQ-L	208.3 ± 12.7 [c]	226.0 ± 71.0 [a]	139.0 ± 31.0 [a]	163.3 ± 31.5 [b]
SQ-E	281.8 ± 21.6 [b]	304.0 ± 29.8 [a]	120.8 ± 36.0 [a]	230.3 ± 25.9 [a]
TP-L	243.5 ± 20.9 [bd]	289.0 ± 50.2 [a]	113.0 ± 14.7 [a]	170.7 ± 28.8 [b]
TP-E	201.5 ± 37.6 [cd]	305.5 ± 54.5 [a]	131.5 ± 23.8 [a]	161.8 ± 27.5 [b]

Welch $F = 31.58$, $P < 0.001$, $\eta^2 = 0.818$, $\omega^2 = 0.783$ (mean absolute reference-to-analog deviation); $F(4,25) = 2.74$, $P = 0.051$, $\eta^2 = 0.304$, $\omega^2 = 0.188$ (transverse plane A–E); $F(4,25) = 0.66$, $P = 0.627$, $\eta^2 = 0.095$, $\omega^2 = -0.048$ (transverse plane B–D); $F(4,25) = 7.72$, $P < 0.001$, $\eta^2 = 0.553$, $\omega^2 = 0.473$ (mean sagittal plane deviation). Within a column, values sharing the same letter did not differ significantly (Games-Howell test for the mean absolute reference-to-analog deviation; Tukey honestly significant difference test for the remaining outcomes). Values of $P < 0.05$ were considered statistically significant. CTRL, commercially available coping; SQ-L, square with limited grooving; SQ-E, square with extensive grooving; TP-L, tapered with limited grooving; TP-E, tapered with extensive grooving.

The mean absolute deviation in the reference-to-analog distances differed significantly among the five impression coping designs (Welch $F = 31.58$, $P < 0.001$; $\eta^2=0.818$). CTRL showed the greatest deviation and differed significantly from all four experimental designs. Among the experimental designs, SQ-E showed greater deviation than SQ-L and TP-E, whereas its difference from TP-L was not significant ($P = 0.066$). TP-L also showed greater deviation than SQ-L ($P = 0.044$) but did not differ from TP-E ($P = 0.214$). Overall, the designs ranked from least to most accurate as CTRL, SQ-E, TP-L, SQ-L, and TP-E (Table 3; Fig. 4).

Impression coping design did not significantly affect either transverse measurement. No significant differences among the designs were found for the intermolar A–E distance ($P = 0.051$) or the interpremolar B–D distance ($P = 0.627$). Across all groups, dimensional deviations were greater for the longer A–E distance than for the shorter B–D distance (Table 3; Figs. 5 and 6).

In the sagittal plane, impression coping design had a significant effect on dimensional deviation ($F = 7.72$, $P < 0.001$; $\eta^2=0.553$). CTRL and SQ-E showed comparable deviations ($P = 0.987$), and both showed significantly greater deviations than SQ-L, TP-L, and TP-E ($P \leq 0.040$). No significant differences were found among the latter three designs ($P \geq 0.991$) (Table 3; Fig. 7).

When the distances from reference analog A to the other four analogs were analyzed separately, impression coping design significantly affected the A→B, A→C, and A→D distances (all $P < 0.001$), but

not the A→E distance (P = 0.296) (Table 4). CTRL showed the greatest deviation at three of the four distances (A→B, A→C, and A→D), whereas its deviation at A→E was comparable to those of the other designs. The performance of SQ-L was distance dependent: it was the most accurate design for the shorter A→B and A→C distances but the second least accurate for the long cross-arch A→D distance. TP-E was the most accurate design for A→D and was among the most accurate designs at the other distances. Overall, the mean deviations in the reference-to-analog distances corresponded to 0.4%–1.6% of the respective distances in the master model (Tables 2 and 4).

Table 4
Mean ±standard deviation of the absolute deviation from the master model for each reference-to-analog distance (μm) (n = 6)

Group	A→B	A→C	A→D	A→E
CTRL	296.8 ± 43.0 [a]	342.7 ± 63.5 [a]	461.5 ± 51.0 [a]	220.5 ± 43.6 [a]
SQ-L	113.7 ± 43.6 [c]	145.5 ± 45.1 [c]	391.8 ± 40.0 [ab]	182.3 ± 39.0 [a]
SQ-E	219.3 ± 52.4 [b]	339.0 ± 48.6 [a]	359.8 ± 50.2 [bc]	208.8 ± 48.9 [a]
TP-L	217.3 ± 35.3 [b]	253.7 ± 28.5 [b]	281.7 ± 72.6 [cd]	221.3 ± 41.9 [a]
TP-E	156.7 ± 48.0 [bc]	244.5 ± 42.4 [b]	227.0 ± 64.4 [d]	177.8 ± 49.0 [a]

$F(4,25) = 14.48$, $P < 0.001$, $\eta^2 = 0.698$ (A→B); $F(4,25) = 17.87$, $P < 0.001$, $\eta^2 = 0.741$ (A→C); $F(4,25) = 15.77$, $P < 0.001$, $\eta^2 = 0.716$ (A→D); $F(4,25) = 1.30$, $P = 0.296$, $\eta^2 = 0.173$ (A→E). Within a column, values sharing the same letter did not differ significantly (Tukey honestly significant difference test). Values of $P < 0.05$ were considered statistically significant. Analog A served as the fixed reference. These distances are the components of the composite outcome and differ from the plane measurements reported in Table 3. *CTRL, commercially available coping; SQ-L, square with limited grooving; SQ-E, square with extensive grooving; TP-L, tapered with limited grooving; TP-E, tapered with extensive grooving.*

None of the casts in any group reproduced the master model exactly.

DISCUSSION

The null hypothesis was partially rejected. Closed-tray impression coping design significantly affected the dimensional accuracy of the definitive casts, but the effect was confined to the mean absolute reference-to-analog deviation and to the sagittal plane; accuracy in the transverse plane was independent of design. The commercially available coping, the design most likely to be encountered clinically, was the least accurate of the 5 tested. These findings indicate that a geometry selected for its retention within the impression is not necessarily the geometry that returns the analog most faithfully to its original position.

The surface features of the designs suggest a mechanism. In SQ-E, the deep indentations distributed over almost the entire axial length must have engaged the elastomer throughout its depth; withdrawal

from such an interlock deformed the surrounding material, and the coping-analog assembly was therefore reseated into a space that had already been distorted. That TP-E, which also resists axial withdrawal through its rounded circumferential bulges, nevertheless performed well suggests that a converging profile permits gradual rather than abrupt separation. The most instructive comparison is TP-L, which offers antirotational retention but essentially none against traction, yet was among the most accurate designs. The shallow steps of the commercially available coping lie in the middle third, leaving the coronal third, the part first engaged during reseating, unmodified; the absence of a coronal locating feature may have permitted a slightly different seating path at each repositioning, although groove position was not varied independently and this interpretation remains an untested assumption.

These observations are largely consistent with the literature. When copings of identical height but different surface geometry were compared, deeper indentations increased retention within the impression material but also raised the risk of distortion, and less retentive shapes were associated with less inaccuracy [9]. Airborne-particle abrasion combined with adhesive coating did not improve accuracy [11]; whereas coping width has been shown to affect it [23]. No surface treatment was applied in the present study, and the differences recorded are therefore attributable to design. No surface treatment was applied in the present study, and the differences recorded are therefore attributable to design. Square copings have been reported to produce more accurate casts than tapered copings [7], and copings with undercuts retained in the impression have been found more accurate than smooth copings removed and repositioned [24]. This advantage, however, is not consistently demonstrated: where tapered and square copings were compared directly, the difference did not reach significance [12], and in most studies coping form has been confounded with impression technique, tapered copings being used with closed trays and square copings with open trays [12–13]. The present findings run counter to the expectation that greater retention yields greater accuracy: SQ-E, which would be expected to be the most retentive design tested, was among the least accurate, whereas TP-L, which offers essentially no traction retention, was among the most accurate. A new closed-tray coping design has been reported to improve impression accuracy significantly [25], whereas studies comparing copings by cross-sectional outline [26] or examining plastic caps [27] found no significant effect. Taken together, these findings suggest that closed-tray coping design affects accuracy not under all conditions but when the geometric variation among the designs compared is sufficiently large.

Although the 5 copings were not the cells of a balanced factorial experiment, 2 of the contrasts they permit bear directly on the attributes of interest. Outline form can be assessed at a matched extent of grooving, because SQ-E and TP-E carried comparably extensive retentive features and TP-E deviated significantly less. The extent of grooving can be assessed within a single outline form, because SQ-E and SQ-L were both parallel walled and the design with the more restrained intaglio was significantly the more accurate. Both attributes therefore acted in the same direction, and the least accurate experimental design was the one that combined a parallel-walled form with extensive grooving.

The absence of a significant difference in the transverse plane deserves comment. In every group, the deviations over the intermolar A–E distance were approximately twice those over the interpremolar B–D

distance; error accumulated with interanalog distance independently of coping design, and the between-group variance was small relative to this component. Among the reference-to-analog distances, A→E was likewise the only one on which coping design had no significant effect. A measurement made between the 2 terminal analogs may therefore be relatively insensitive to coping geometry, accuracy in that direction being governed less by the coping than by the accumulated dimensional behavior of the impression material and the stone over a long distance. Site dependence was also evident for SQ-L, which was the most accurate design over the short A→B and A→C distances but fell among the least accurate over the long cross-arch A→D distance. TP-E, by contrast, remained among the most accurate at every site including A→D, which suggests that a converging outline form confers a consistency that a parallel-walled form does not, irrespective of how extensive the retentive features are.

The deviations recorded should be considered against the misfit that an implant-supported prosthesis is known to tolerate. A systematic review of misfit tolerance concluded that a clinical threshold cannot yet be determined, but reported that vertical misfits of 30 to 160 μm and a horizontal misfit of 150 μm were not associated with mechanical complications, and that the mechanical response to misfit is more critical than the biological one [28]. In the present study, the mean absolute reference-to-analog deviation ranged from 201.5 to 330.4 μm and the mean sagittal plane deviation from 161.8 to 240.0 μm, so every group exceeded the horizontal threshold. These values describe the definitive cast rather than a completed framework, and the 2 are not proportional, because a framework fabricated on a distorted cast may be distorted in a compensating direction. Even so, the finding that no group fell within the range associated with an absence of mechanical complications supports the view that a closed-tray impression should not be relied upon for a multi-unit prosthesis without verification. Misfit of this order has nevertheless been recorded clinically without a demonstrable effect on marginal bone level, which indicates that the biological tolerance is wider than the mechanical one [29].

This study has limitations. Under in vitro conditions the direction and angulation of tray withdrawal could not be reproduced [30], saliva, intraoral temperature and humidity were absent, and the surface properties of an acrylic resin master model differ from those of the peri-implant mucosa. Only 1 impression material, 1 implant system, and a completely edentulous maxillary configuration with parallel analogs were examined, so the findings should not be extrapolated to angulated implants, partially edentulous arches, or digital workflows. Because the designs did not constitute a balanced factorial arrangement, the convergence angle covaried with the extent of grooving and groove depth was not measured, the effect of any single geometric attribute cannot be quantified. Six casts per group provided adequate power for the primary outcome and for the sagittal plane but not for the transverse plane, where the absence of significance should be read as a failure to detect an effect rather than as evidence that none exists. Because homogeneity of variance was not satisfied, the sensitivity analyses did not agree at every contrast, although the contrasts separating SQ-E remained significant under both post hoc tests. Each distance was measured once, so intraexaminer reliability could not be quantified. Future research should incorporate simulated intraoral conditions, angulated implants, and comparison with intraoral scanning.

No cast in any group reproduced the master model exactly [21]. The contribution of this study is to show that, in closed-tray impression copings, retention and accuracy are distinct properties that become competing beyond a certain point. Extending the retentive surface features held the coping more securely within the impression but did not improve the accuracy of the definitive cast, and impaired it when combined with a parallel-walled form. Given that the closed-tray technique is often a necessity rather than a preference, a converging outline form or a surface with limited retentive grooving is one of the few options through which the clinician can improve impression accuracy without changing the material or the technique. However, because the dimensional deviation exceeded the reported mechanical tolerance thresholds even for the most accurate design, coping selection does not replace verification procedures.

CONCLUSIONS

Within the limitations of this in vitro study, the design of the closed-tray impression coping significantly affected the dimensional accuracy of implant definitive casts. The commercially available coping was the least accurate of the 5 designs tested. The square coping with deep grooves covering almost the entire surface was significantly less accurate than the square coping with limited grooving and the tapered coping with extensive grooving, whereas accuracy in the transverse plane was independent of design. Clinically, these findings indicate that a tapered coping or one with limited retentive grooving should be preferred in the closed-tray technique, and that extending the grooving over the surface in order to increase retention impairs rather than improves accuracy. Because the mean absolute reference-to-analog deviation exceeded the mechanical tolerance thresholds reported for passive fit even for the most accurate design, closed-tray impressions for multi-unit implant prostheses should be used together with verification procedures. Future research should examine the isolated effect of groove depth in a balanced factorial design and under intraoral conditions.

ABBREVIATIONS

ANOVA
analysis of variance
CAD
computer-aided design
CTRL
commercially available closed-tray impression coping (control group)
ELI
extra-low interstitial
SQ-E
square coping with extensive grooving
SQ-L
square coping with limited grooving
STL

standard tessellation language
TP-E
tapered coping with extensive grooving
TP-L
tapered coping with limited grooving

DECLARATIONS

Ethics approval and consent to participate:

This study was approved by the Non-interventional Clinical Research Ethics Committee of Cumhuriyet University (decision no. 2020-12/30). The study was an in vitro laboratory investigation that did not involve human participants, human tissue, or animals; consent to participate was therefore not applicable.

Consent for publication:

Not applicable.

Competing Interests

The coping used as the control (MomentDent; ESTAŞ Medikal A.Ş.) is a commercially available product of the same manufacturer. The 4 experimental designs were developed as candidate improvements on this existing product, and their design and manufacture were carried out by ESTAŞ Eksantrik Sanayi ve Ticaret A.Ş., which also provided the impression copings and implant analogs free of charge. The impressions, cast fabrication, and all measurements were performed independently in the research laboratory of Sivas Cumhuriyet University by an operator blinded to group allocation. The authors declare no other competing interests.

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Author Contribution

GÇ: Investigation, Methodology, Validation, Data Curation, Formal Analysis, Writing – Original Draft. MÜ: Conceptualization, Methodology, Supervision, Project Administration, Funding Acquisition, Resources, Writing – Original Draft, Writing – Review & Editing. All authors have contributed significantly, are in agreement with the manuscript, and have read and approved the final version.

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Availability of data and materials:

The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

REFERENCES

1. Pjetursson BE, Thoma D, Jung R, Zwahlen M, Zembic A. A systematic review of the survival and complication rates of implant-supported fixed dental prostheses (FDPs) after a mean observation period of at least 5 years. Clin Oral Implants Res. 2012;23(Suppl 6):22–38. https://doi.org/10.1111/j.1600-0501.2012.02546.x.
2. Papaspyridakos P, Chen CJ, Chuang SK, Weber HP, Gallucci GO. A systematic review of biologic and technical complications with fixed implant rehabilitations for edentulous patients. Int J Oral Maxillofac Implants. 2012;27(1):102–10.
3. Kallus T, Bessing C. Loose gold screws frequently occur in full-arch fixed prostheses supported by osseointegrated implants after 5 years. Int J Oral Maxillofac Implants. 1994;9(2):169–78.
4. Sahin S, Cehreli MC. The significance of passive framework fit in implant prosthodontics: current status. Implant Dent. 2001;10(2):85–92. https://doi.org/10.1097/00008505-200104000-00003.
5. Chee W, Jivraj S. Impression techniques for implant dentistry. Br Dent J. 2006;201(7):429–32. https://doi.org/10.1038/sj.bdj.4814118.
6. Brånemark PI. Osseointegration and its experimental background. J Prosthet Dent. 1983;50(3):399–410. https://doi.org/10.1016/s0022-3913(83)80101-2.
7. Del'Acqua MA, Arioli-Filho JN, Compagnoni MA, Mollo FA Jr. Accuracy of impression and pouring techniques for an implant-supported prosthesis. Int J Oral Maxillofac Implants. 2008;23(2):226–36.
8. Pera F, Pesce P, Bevilacqua M, Setti P, Menini M. Analysis of different impression techniques and materials on multiple implants through 3-dimensional laser scanner. Implant Dent. 2016;25(2):232–

7. https://doi.org/10.1097/ID.0000000000000353.
9. Rashidan N, Alikhasi M, Samadizadeh S, Beyabanaki E, Kharazifard MJ. Accuracy of implant impressions with different impression coping types and shapes. Clin Implant Dent Relat Res. 2012;14(2):218–25. https://doi.org/10.1111/j.1708-8208.2009.00241.x.
10. Liou AD, Nicholls JI, Yuodelis RA, Brudvik JS. Accuracy of replacing three tapered transfer impression copings in two elastomeric impression materials. Int J Prosthodont. 1993;6(4):377–83.
11. Vigolo P, Fonzi F, Majzoub Z, Cordioli G. An evaluation of impression techniques for multiple internal connection implant prostheses. J Prosthet Dent. 2004;92(5):470–6. https://doi.org/10.1016/j.prosdent.2004.08.015.
12. Cabral LM, Guedes CG. Comparative analysis of 4 impression techniques for implants. Implant Dent. 2007;16(2):187–94. https://doi.org/10.1097/ID.0b013e3180587b3f.
13. Assuncao WG, Gennari Filho H, Zaniquelli O. Evaluation of transfer impressions for osseointegrated implants at various angulations. Implant Dent. 2004;13(4):358–66. https://doi.org/10.1097/01.id.0000144509.58901.f7.
14. Gennari Filho H, Mazaro JVQ, Vedovatto E, Assunção WG, dos Santos PH. Accuracy of impression techniques for implants. Part 2 – comparison of splinting techniques. J Prosthodont. 2009;18(2):172–6. https://doi.org/10.1111/j.1532-849X.2008.00325.x.
15. Assunção WG, Tabata LF, Cardoso A, Rocha EP, Gomes EA. Prosthetic transfer impression accuracy evaluation for osseointegrated implants. Implant Dent. 2008;17(3):248–56. https://doi.org/10.1097/ID.0b013e318182ef58.
16. Ghanem RA, Nassani MZ, Baroudi K, Abdel Fattah A. Dimensional accuracy of different techniques used for complete-arch multi-implant impressions. J Investig Clin Dent. 2016;7(3):225–31. https://doi.org/10.1111/jicd.12160.
17. Alikhasi M, Bassir SH, Naini RB. Effect of multiple use of impression copings on the accuracy of implant transfer. Int J Oral Maxillofac Implants. 2013;28(2):408–14. https://doi.org/10.11607/jomi.2717.
18. Wassell RW, Barker D, Walls AWG. Crowns and other extra-coronal restorations: impression materials and technique. Br Dent J. 2002;192(12):679–84. https://doi.org/10.1038/sj.bdj.4801456.
19. Christensen GJ. Impressions are changing: deciding on conventional, digital or digital plus in-office milling. J Am Dent Assoc. 2009;140(10):1301–4. https://doi.org/10.14219/jada.archive.2009.0054.
20. Holst S, Blatz MB, Bergler M, Goellner M, Wichmann M. Influence of impression material and time on the 3-dimensional accuracy of implant impressions. Quintessence Int. 2007;38(1):67–73.
21. Lee H, So JS, Hochstedler JL, Ercoli C. The accuracy of implant impressions: a systematic review. J Prosthet Dent. 2008;100(4):285–91. https://doi.org/10.1016/S0022-3913(08)60208-5.
22. Marghalani A, Weber HP, Finkelman M, Kudara Y, El Rafie K, Papaspyridakos P. Digital versus conventional implant impressions for partially edentulous arches: an evaluation of accuracy. J Prosthet Dent. 2018;119(4):574–9. https://doi.org/10.1016/j.prosdent.2017.07.002.

23. Alkindi S, Hamdoon Z, Aziz AM. Effect of different impression coping and scan body designs on the accuracy of conventional versus digital implant impressions: an in vitro study. J Dent. 2024;146:105045. https://doi.org/10.1016/j.jdent.2024.105045.
24. Assif D, Fenton A, Zarb G, Schmitt A. Comparative accuracy of implant impression procedures. Int J Periodontics Restor Dent. 1992;12(2):112–21.
25. Roig E, Álvarez-Maldonado N, Garza LC, Vallés M, Espona J, Roig M. Impact of design and length on the accuracy of closed tray transfer copings. J Clin Exp Dent. 2019;11(8):e707–12. https://doi.org/10.4317/jced.55588.
26. Osman M, Abubakr NH, Suliman A, Ziada H. The impact of impression coping geometrical design on accuracy of implant impressions: an experimental study. Int J Implant Dent. 2020;6(1):54. https://doi.org/10.1186/s40729-020-00256-0.
27. Coşkun A, Koyu T, Yeşilyurt G, Ülgey M, Görler O. Effect of plastic impression-transfer copings on the dimensional accuracy of implant impressions. Cumhuriyet Dent J. 2023;26(1):42–6.
28. Abdelrehim A, Etajuri EA, Sulaiman E, Sofian H, Salleh NM. Magnitude of misfit threshold in implant-supported restorations: a systematic review. J Prosthet Dent. 2024;132(3):528–35. https://doi.org/10.1016/j.prosdent.2022.09.010.
29. Jemt T, Book K. Prosthesis misfit and marginal bone loss in edentulous implant patients. Int J Oral Maxillofac Implants. 1996;11(5):620–5.
30. Seif MM, Abdel Hakim AA, Abouelkheir HM, Negm RA. Comparison of transfer accuracy among hexed implant mounts, clips impression copings, and open-tray impression copings at different implant angulations: an in vitro study. BMC Oral Health. 2025;25(1):928. https://doi.org/10.1186/s12903-025-06304-8.

Figures

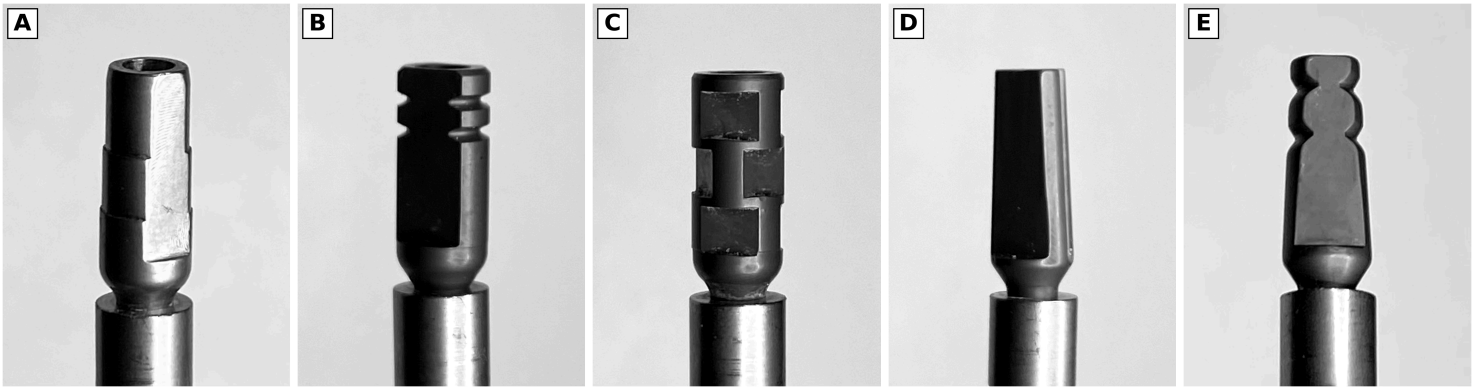


Figure 1

Closed-tray impression coping designs. A, CTRL (commercially available coping). B, SQ-L. C, SQ-E. D, TP-L. E, TP-E.

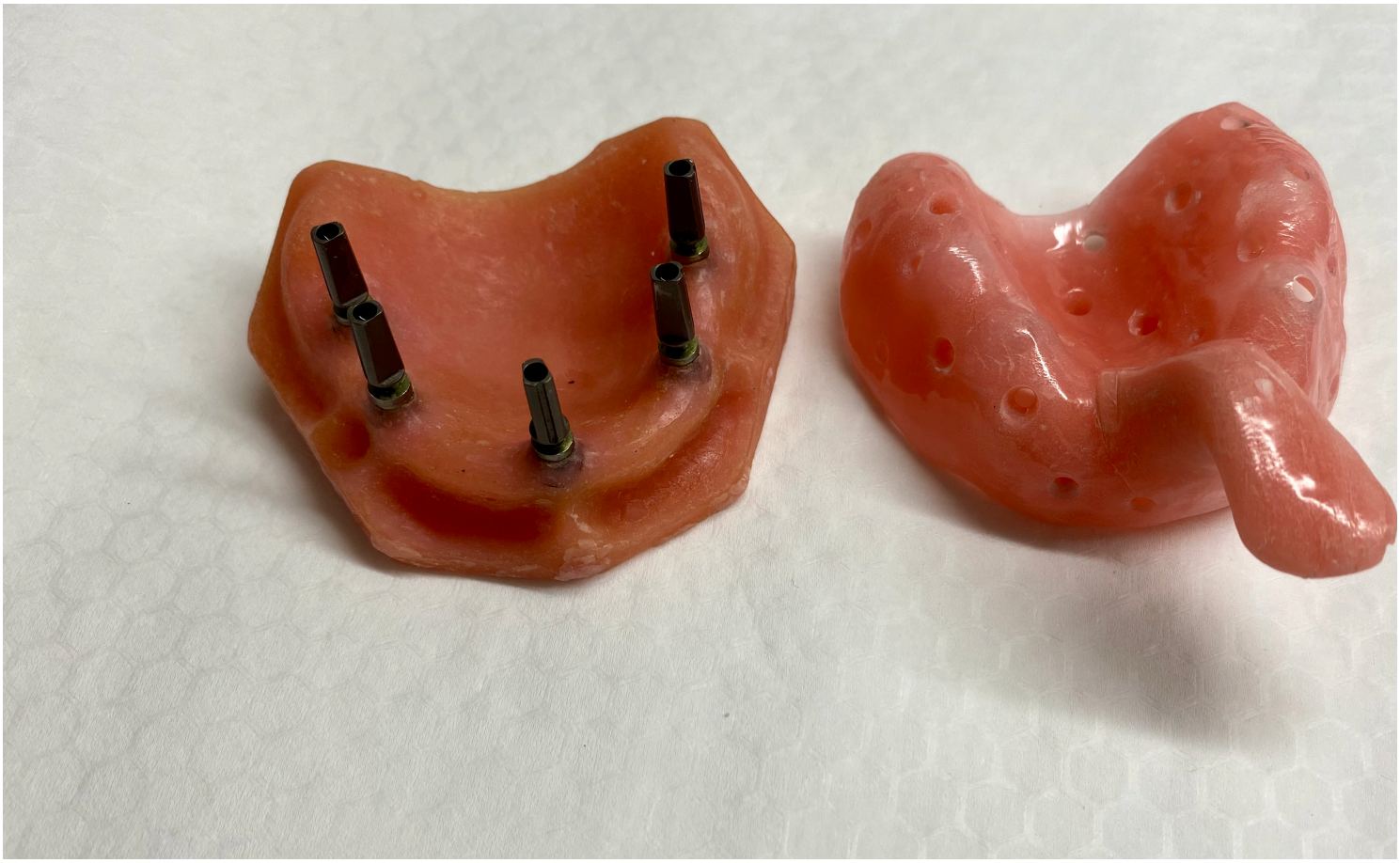


Figure 2

Edentulous maxillary master model and perforated custom tray. The autopolymerizing acrylic resin master model carries five implant analogs (A through E).

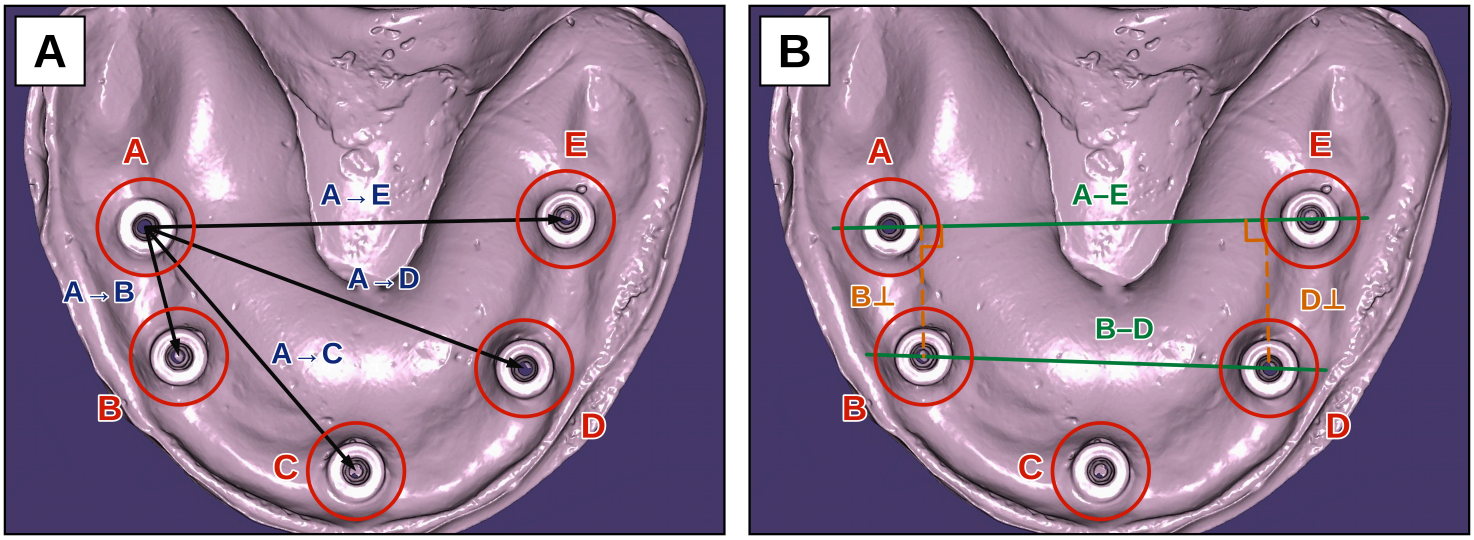


Figure 3

Schematic representation of the 2 measurement sets on the digitized master model. A, the 4 reference-to-analog distances recorded from the fixed reference analog A (A→B, A→C, A→D, A→E). B, transverse-plane measurements (solid lines; intermolar A–E and interpremolar B–D) and sagittal-plane measurements (dashed lines; the B⊥ and D⊥ perpendiculars dropped from analogs B and D to the intermolar A–E line).

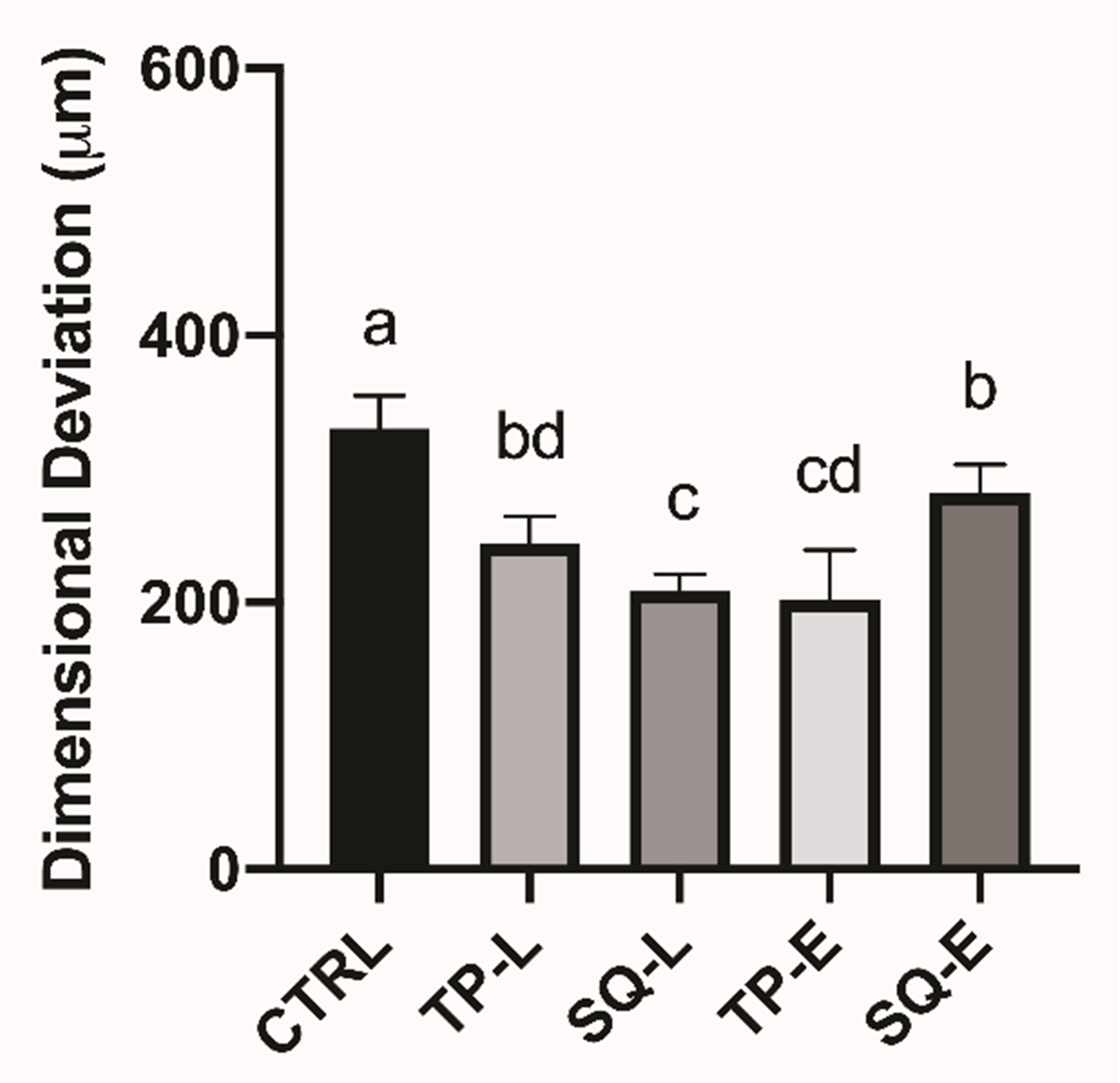


Figure 4

Mean absolute reference-to-analog deviation by impression coping design. Error bars represent standard deviations. Groups sharing the same letter did not differ significantly (Games-Howell test, P<0.05).

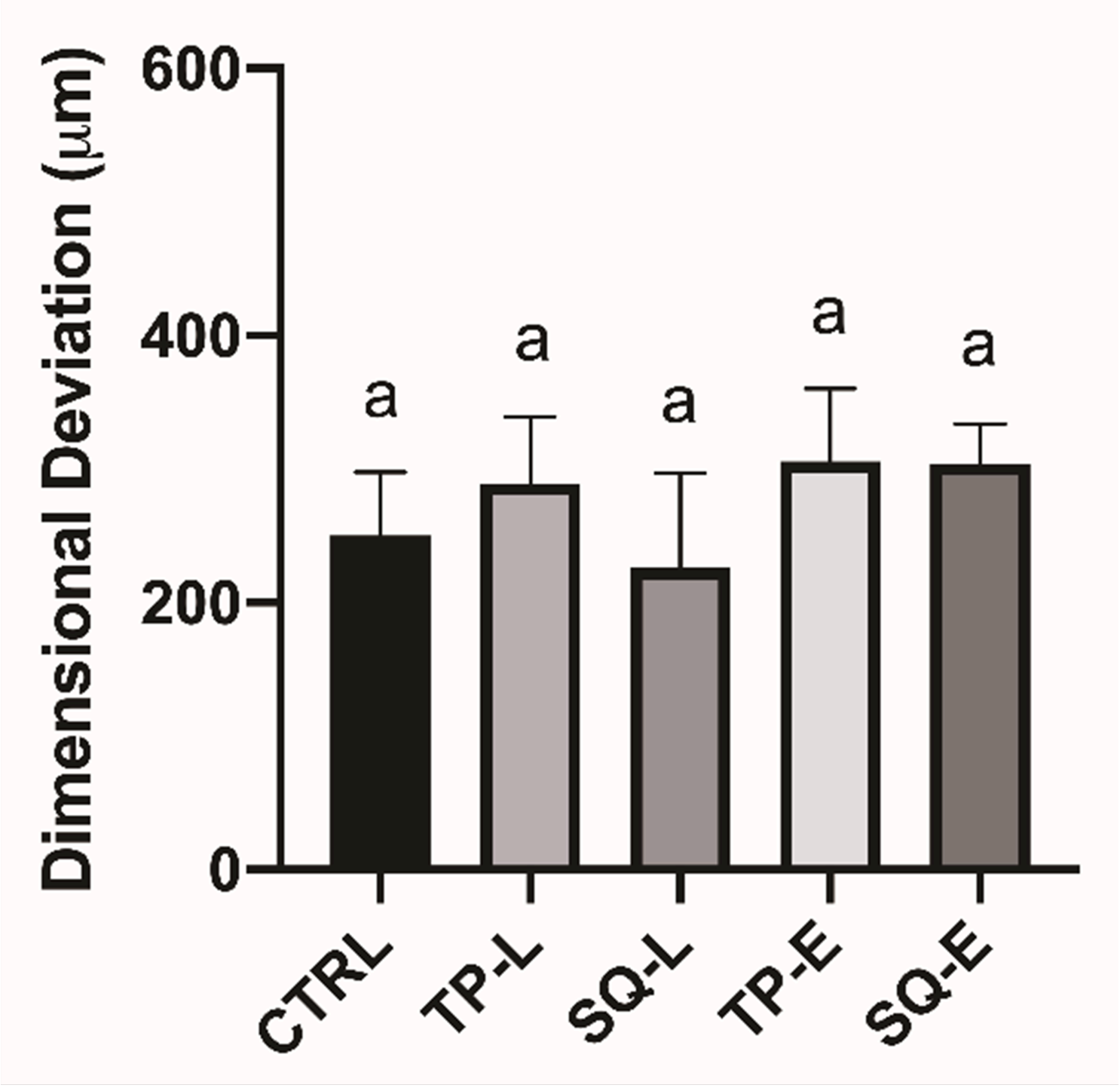


Figure 5

Deviation over the intermolar A–E distance in the transverse plane. Error bars represent standard deviations. Groups sharing the same letter did not differ significantly (Tukey honestly significant difference test, P<0.05).

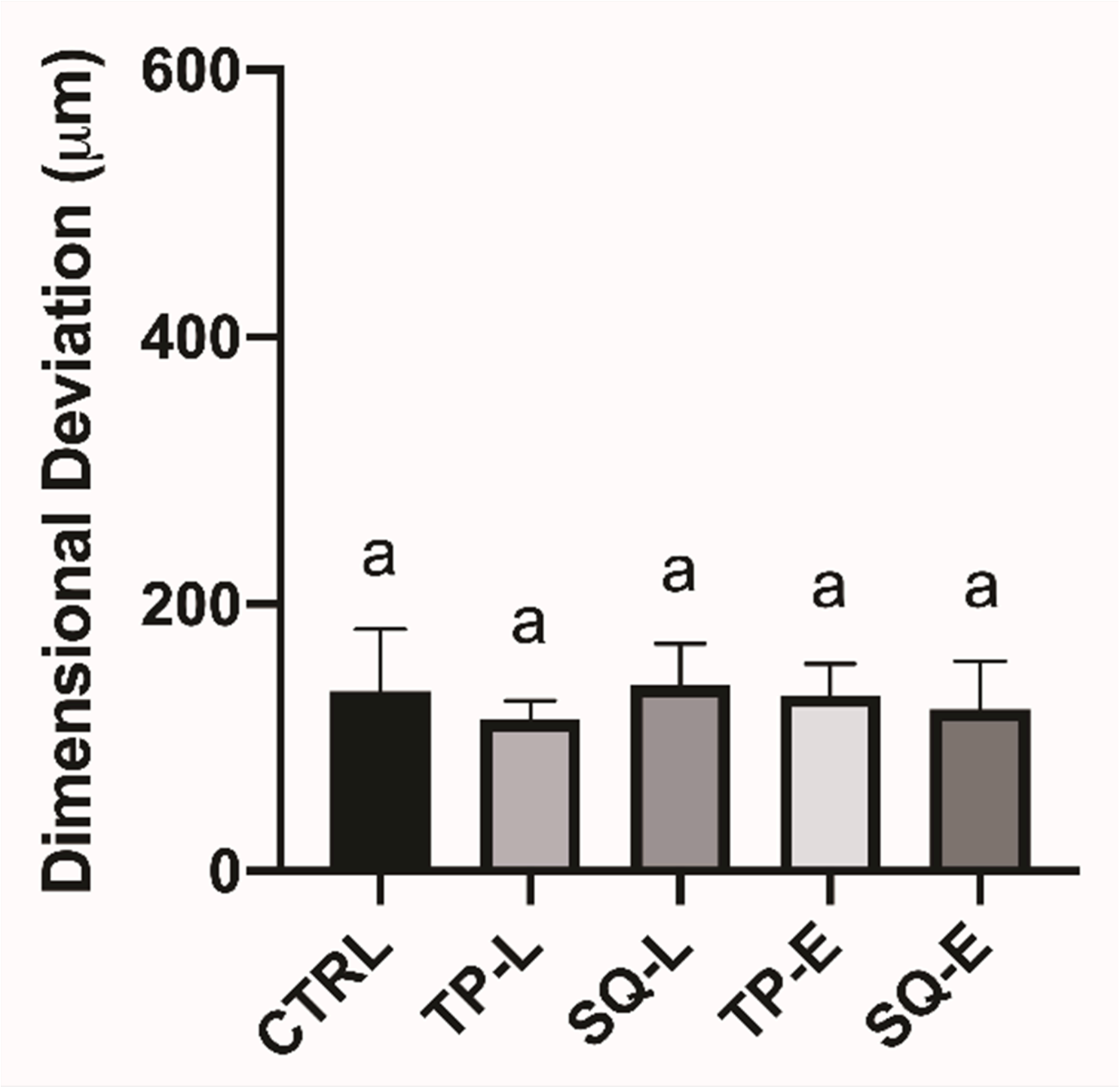


Figure 6

Deviation over the interpremolar B–D distance in the transverse plane. Error bars represent standard deviations. Groups sharing the same letter did not differ significantly (Tukey honestly significant difference test, $P<0.05$).

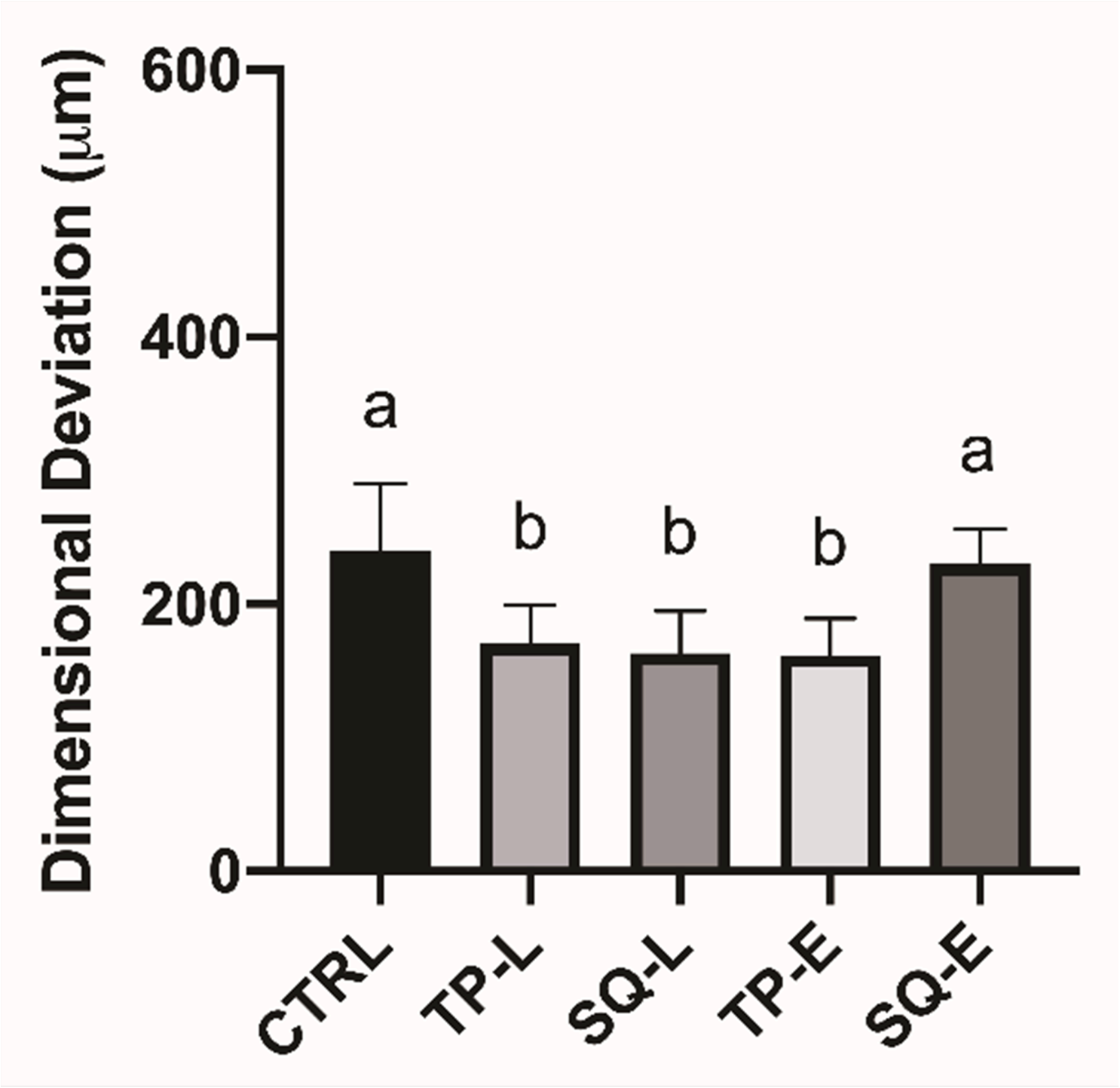


Figure 7

Mean deviation in the sagittal plane. Error bars represent standard deviations. Groups sharing the same letter did not differ significantly (Tukey honestly significant difference test, $P<0.05$).