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Study of prepared tooth displacement based on digital jaw model comparison

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ABSTRACT

BACKGROUND: Despite extensive research on the prevention and treatment of dentoalveolar shifts in cases of dental arch defects, which develop over time, there is a lack of studies examining errors related to the displacement of prepared teeth during the laboratory fabrication of a prosthetic restoration.

With the introduction of digital technologies in clinical practice, it has become possible to assess the displacement of a prepared tooth and determine the optimal treatment duration.

CLINICAL CASE DESCRIPTION: This report presents a clinical case of prosthetic treatment in a patient diagnosed with “hard tissue defect of tooth 2.6, occlusal surface destruction index $\geq 60\%$,” using a digital protocol.

To analyze the extent of displacement of the prepared tooth toward the antagonists over a known period, the distance to the antagonist teeth was measured using digital models.

Digital images of the jaw models obtained immediately after tooth preparation were designated as baseline data. After 24 days, new impressions were taken, and the corresponding digital models were recorded as current data.

The digital models were superimposed in the position of centric occlusion, and the distances in the baseline and current datasets were measured ten times. To assess the displacement of the prepared tooth, the measured values were compared.

This clinical case justified the duration of prosthetic treatment considering the displacement error of the prepared tooth based on digital model comparison. Statistically significant differences were found between the measurements taken over the specified time period. The mean value of the initial measurements was 1.345 ± 0.005 mm, while the mean value of the current measurements was 1.229 ± 0.003 mm. The difference between these values indicates that the prepared tooth shifted by 0.116 ± 0.002 mm (116 ± 2 μ m).

CONCLUSION: Considering the clinical findings of this study, it is recommended that fixed prosthetic treatment without the use of temporary restorations be completed within the shortest possible timeframe. The measured displacement of the prepared tooth toward the antagonist teeth, as observed on digital jaw models, indicates that laboratory fabrication of a prosthesis without a temporary restoration beyond 24 days is critical, as it leads to prosthetic misfit.

Keywords: clinical case of prepared tooth displacement; duration of dental prosthetics; digital technologies in dentistry.

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Исследование смещения одонтопрепарированного зуба на основе сравнения цифровых моделей челюстей

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АННОТАЦИЯ

Обоснование. При достаточном многообразии работ, которые посвящены профилактике и лечению денто-альвеолярных перемещений при дефектах зубных рядов, проявляющихся с течением времени, отсутствуют исследования погрешностей, связанных со смещением одонтопрепарированных зубов в промежуток времени лабораторного изготовления ортопедической конструкции.

С использованием цифровых технологий в клинике стало возможным оценить смещение одонтопрепарированного зуба и сделать вывод о надлежащей продолжительности лечения.

Описание клинического случая. Представлен клинический случай ортопедического лечения пациента с диагнозом «дефект твёрдых тканей зуба 2.6, индекс разрушения окклюзионной поверхности зуба $\geq 60\%$ » с использованием цифрового протокола.

Для анализа данных о расстоянии, на которое за известный период времени сместился одонтопрепарированный зуб навстречу антагонистам, измеряли расстояние до зубов-антагонистов с цифровых моделей.

Цифровые изображения моделей челюстей, полученные сразу после одонтопрепарирования, обозначили как исходные данные. По прошествии 24 дней после снятия первых оттисков полученные по снятым повторно оттискам цифровые модели обозначили как текущие данные.

Программное совмещение моделей зубных рядов в позицию центральной окклюзии и измерение расстояния исходных и текущих данных проводили по 10 раз. Для оценки смещения одонтопрепарированного зуба их значения сравнивали.

Данный клинический случай позволил обосновать длительность ортопедического лечения с учётом погрешности смещения одонтопрепарированного зуба на основе сравнения цифровых моделей челюстей. Между измерениями, проведёнными в известный промежуток времени, обнаружены статистически значимые различия. Среднее значение величин данных исходной ситуации составляет $1,345 \pm 0,005$ мм, среднее значение величин данных текущей ситуации — $1,229 \pm 0,003$ мм. Разница между измерениями позволяет сделать вывод о том, что произошло смещение одонтопрепарированного зуба на $0,116 \pm 0,002$ мм (116 ± 2 мкм).

Заключение. Учитывая клинический результат исследования, можно рекомендовать ортопедическое лечение несъёмными конструкциями без использования временной конструкции в кратчайший промежуток времени. Измеренное на цифровых моделях челюстей перемещение одонтопрепарированного зуба в направлении зубов-антагонистов показывает, что продолжительность лабораторного изготовления протеза без использования временной конструкции более 24 дней является критической, приводящей к дефектности зубного протеза.

Ключевые слова: клинический случай смещения одонтопрепарированного зуба; продолжительность зубного протезирования; цифровые технологии в стоматологии.

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BACKGROUND

The planned 3D morphology of artificial teeth can be accurately reproduced in actual restorations using CAD/CAM technologies [1, 2]. A decisive criterion for the quality of fabricated prostheses is the spatial correspondence between the abutment teeth in the oral cavity and the laboratory model, which ensures high precision in positioning fixed dental prostheses and achieving marginal adaptation of artificial crowns.

One of the key aspects of attaining this outcome is the use of provisional restorations. In clinical practice, nonadherence—for various reasons—to recommendations requiring provisional restorations often compromises accurate prosthesis positioning, because displacement of the prepared teeth goes unnoticed. In such cases, clinicians often resort to chairside adjustments, which may resolve the immediate misfit issue but fail to ensure the precision of the final prosthesis. As a result, restorations fabricated in this manner do not fully meet clinical requirements.

Tooth preparation disrupts the morphological integrity of the dental arch with adjacent and opposing teeth. The resulting defects in the dental arch lead, over time, to complex adaptive changes that manifest clinically as tooth movement and altered occlusal contacts, considered to be secondary deformations.

Although numerous studies have examined the prevention and treatment of tooth movement in cases of dental arch defects occurring over extended periods [3], the scientific publications lack investigations into displacement errors of prepared teeth during the laboratory fabrication period of fixed prostheses. The opportunity to quantify such displacement relative to antagonist teeth arose during the analysis of a clinical case of prosthetic treatment using digital technologies.

The functionality of digital software allows automated simulation of mandibular teeth movement relative to the maxillary teeth in the horizontal plane until occlusal contact is established between the prepared tooth and its antagonist, without altering the relative positioning of the models.

The use of this approach for distance measurement must account for occlusal inaccuracies, such as occlusal interferences or excessive separation of virtual models, which may not correspond to the patient's actual occlusal relationships and may introduce measurement errors [4, 5]. Therefore, special attention was given to the accuracy of transferring interarch relationships into the digital environment and to the validity of measurements obtained through alignment of digital models.

The clinical case presented below substantiates the recommended duration of prosthetic treatment, considering the displacement error of the prepared tooth, as assessed by digital jaw model comparison.

CASE DESCRIPTION

A clinical case of prosthetic treatment was performed in patient A, born in 1972, using a digital protocol. The diagnosis was hard tissue defect of maxillary left first molar (tooth 26, FDI/ISO designation) with an occlusal surface destruction index $\geq 60\%$ (ICD-10 code K02.9).

The treatment plan included fabrication of a minimally invasive full-contour zirconia crown using computer-aided milling of digitized dental casts. Impressions of the maxillary and mandibular arches were obtained, and the plaster casts were scanned with a laboratory scanner. During fabrication of the definitive restoration, a provisional crown made of photopolymer material was produced using stereolithography on a 3D printer, based on digital imaging data.

The patient did not attend the scheduled appointment for placement of the provisional crown on the prepared tooth. The next clinical visit took place 24 days after tooth preparation. Tooth 26 showed no morphological defects or other signs of hard tissue damage on visual examination (see Fig. 1).

However, intraoral positioning of the provisional crown on tooth 26 differed from its fit on the model and was assessed as unsatisfactory (see Figs. 2 and 3).

New impressions of the dental arches were obtained, and the resulting plaster casts were rescanned to produce updated digital images.



Fig. 1. Absence of visible morphological defects or hard tissue damage of prepared tooth 26.



Fig. 2. Provisional crown for tooth 26 on the dental model.



Fig. 3. Unsatisfactory intraoral positioning of the provisional crown on tooth 26.

When the digital models of the maxillary arch obtained immediately after preparation and after 24 days were superimposed in the virtual environment, a positional discrepancy of the prepared tooth was visualized. This clinical case provided the opportunity to measure the displacement of the prepared tooth during this interval.

To quantify prepared tooth displacement, a study design was developed and schematically illustrated in Fig. 4. The digital dental models obtained immediately after tooth preparation were designated as baseline data, whereas those produced from the repeated impressions after 24 days were designated as current data.

In the baseline clinical situation (immediately after preparation of tooth 26) and in the current clinical situation (24 days later), impressions of the maxillary and mandibular arches were obtained using a two-step impression technique with Speedex light body (Coltene, Switzerland). In the laboratory, high-strength plaster casts were fabricated with Fujirock (GC, Japan) using standard procedures.

For scanning, a laboratory scanner (Autoscan DS-EX PRO, Shining3D, China) was used. The maxillary and mandibular models were manually positioned in maximum intercuspation, fixed together, and scanned as a unit. Each model was then scanned separately.

To analyze the displacement of tooth 26 toward its antagonists over the specified period, the distances to the antagonist teeth were measured from the digital models. For this purpose, the scanned models were imported into DentalCAD 3.0 Galway (Exocad, Germany).

Digital alignment of the models in centric occlusion and measurement of the distances were performed 10 times for both baseline and current datasets (see Fig. 5).

Using the "Distance" tool, the models were moved toward each other in the horizontal plane until minimal occlusal contact was visualized on the prepared tooth

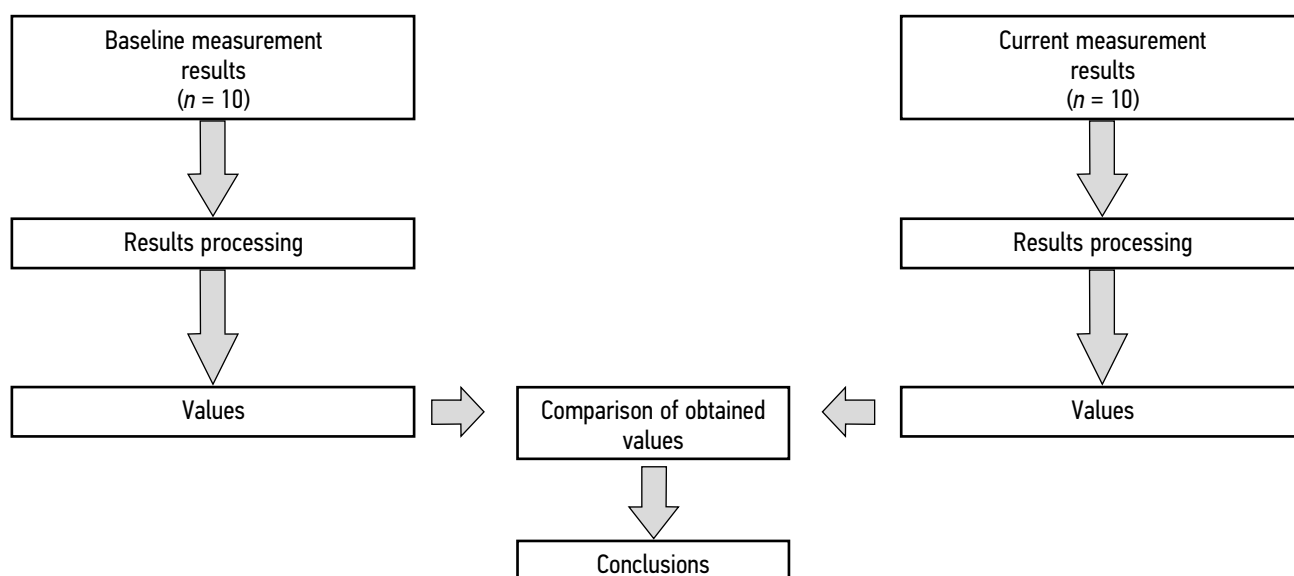


Fig. 4. Study design.

and its antagonist. Contact points were identified by the appearance of blue markers on the surfaces of the prepared tooth and antagonist (see Fig. 6).

Using the “Ruler” tool, two points were marked: one at the center of the contact area on tooth 26 and the other at the center of the contact area on the antagonist tooth (see Fig. 7). The software automatically calculated

the distance (in micrometers) between these points, which represented the target measurement. All values were recorded in a table, and baseline and current data were compared to assess prepared tooth displacement.

Statistical analysis was performed using SPSS Statistics, version 21 (IBM, USA). The critical p -values were as follows: baseline data, $p = 0.832$; current data,

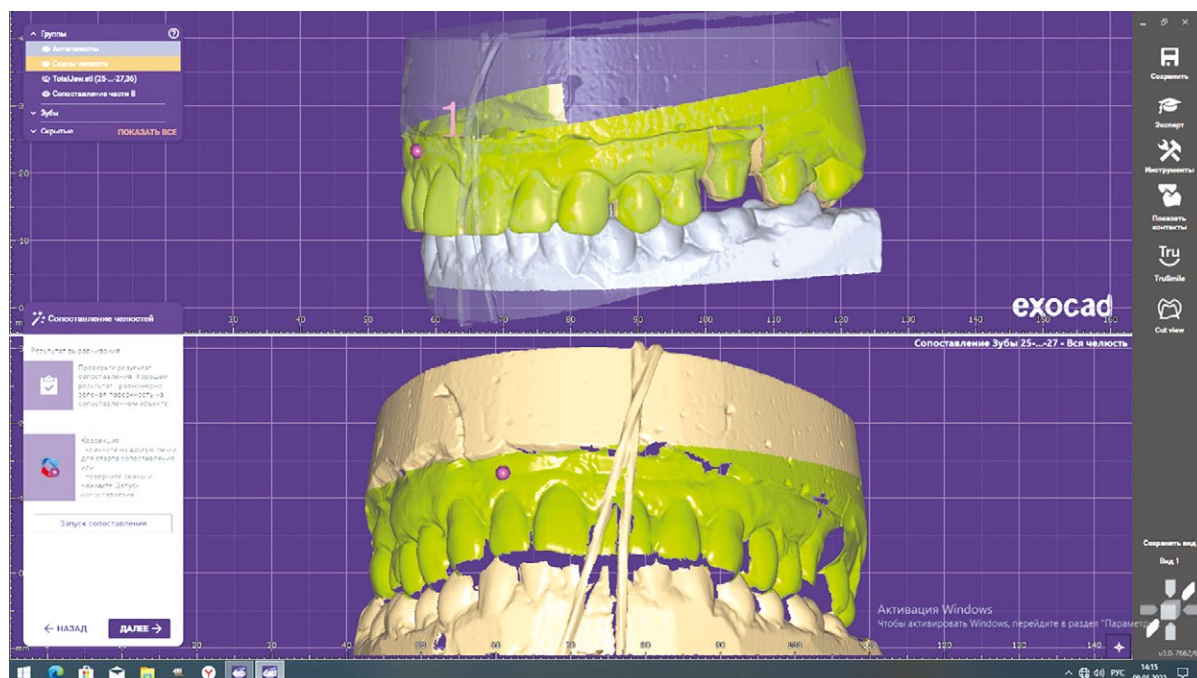


Fig. 5. Example of alignment of maxillary and mandibular models in centric occlusion.

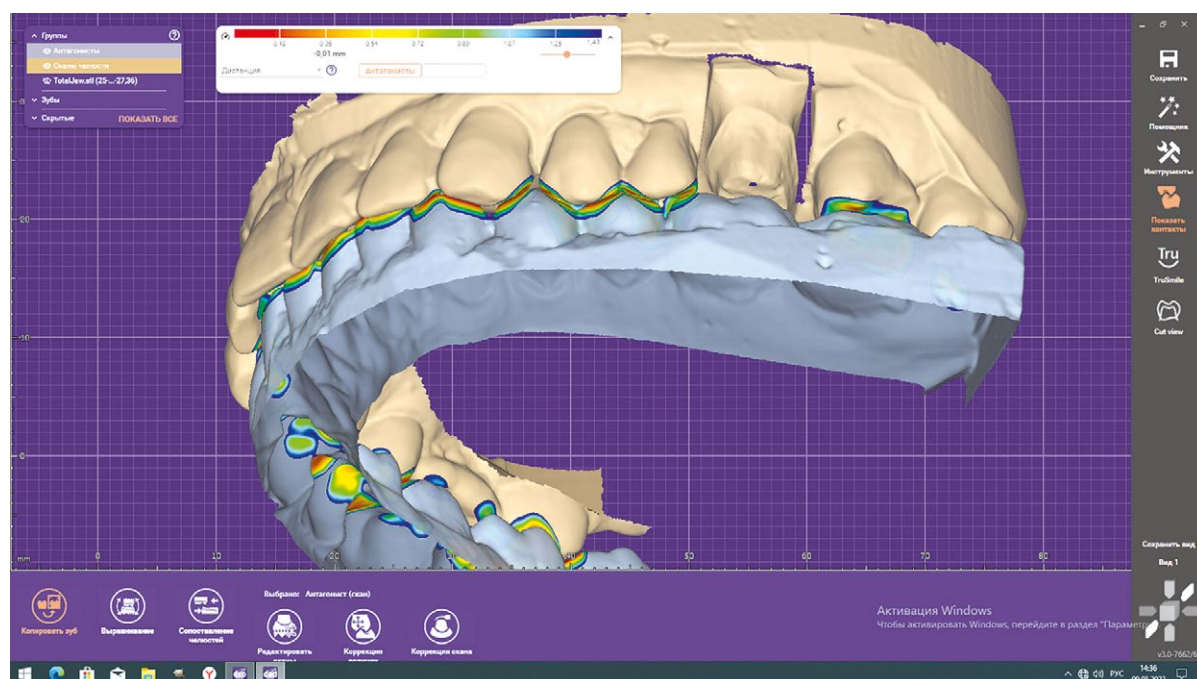


Fig. 6. Visualization of blue contact points on the prepared tooth and antagonist using the “Distance” tool.

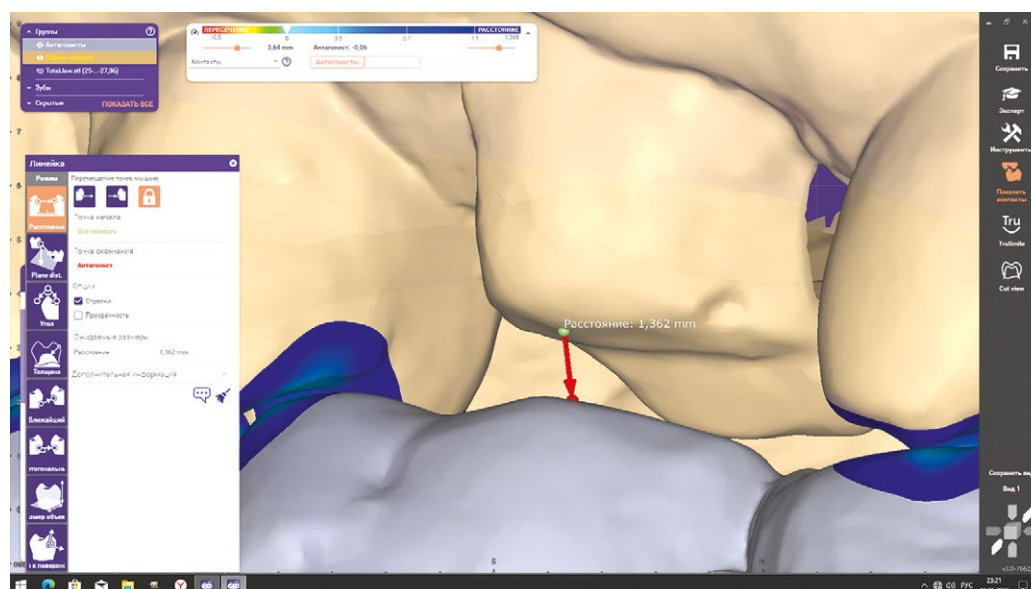


Fig. 7. Measurement with the “Ruler” tool: point marked at the center of the contact area on tooth 26 and on the antagonist tooth.

$p = 0.825$. Since both values exceeded 0.05, normality of distribution was confirmed using the Kolmogorov–Smirnov Z-test, and homogeneity of variance was assessed using the Fisher F -test. Comparative analyses of the data were carried out using the Mann–Whitney U test and Student’s t -test for nonparametric samples.

The measurements of the distance between the prepared tooth 26 and its antagonist at baseline and current data collection are presented in Table 1.

Descriptive statistics (see Table 2) and visual inspection of histograms (see Fig. 8) provided a qualitative assessment of distribution characteristics. The analysis showed that the distributions of all variables deviated from normality, as absolute values of skewness and kurtosis exceeded 1.

In two measurements, the variance equaled 0, indicating statistical significance of these observations.

Analysis of baseline descriptive statistics demonstrated that the minimum value was 1.333 mm, the maximum was 1.351 mm, and the mean was 1.345 mm (SE, 0.001543 mm; SD, 0.004881 mm). These values were close to zero, which indicates stability of the parameter in the general population. The skewness was -1.467 , indicating a shift of most values toward higher measurements relative to the mean. The kurtosis was 3.405, indicating a platykurtic distribution, with a less pronounced peak compared with a normal distribution (see Table 2).

Analysis of current descriptive statistics showed a minimum of 1.224 mm, a maximum of 1.233 mm, and a mean of 1.22930 mm (SE, 0.001033 mm; SD, 0.003268 mm). These values were also close to zero, indicating stability within the general population. The

skewness was -0.262 , again suggesting a shift of most values toward higher measurements. The kurtosis was -1.552 , indicating a leptokurtic distribution with a more elongated shape than that of a normal distribution (see Table 2).

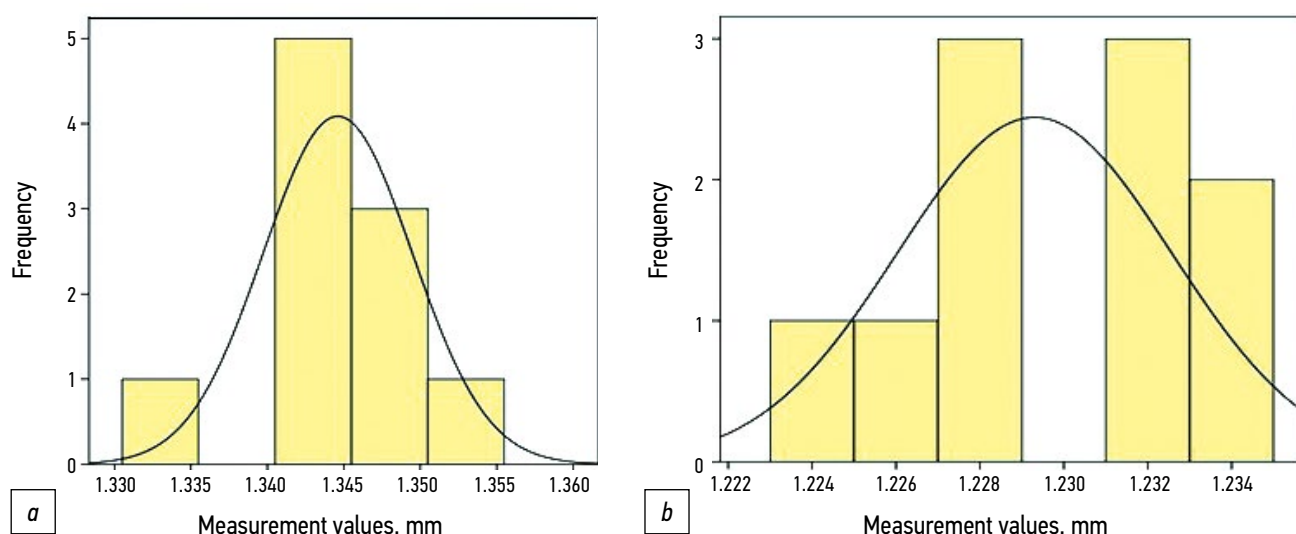
Kolmogorov–Smirnov Z test results (see Table 3) showed asymptotic significance values of 0.832 and 0.825 ($p > 0.05$), confirming deviation from normal distribution.

Table 1. Distance measurements between prepared tooth 26 and antagonist tooth at baseline and current data collection (mm)

Number of measurements	Baseline measurement values (mm)	Current values (mm)
1	1.348	1.226
2	1.345	1.224
3	1.345	1.227
4	1.348	1.233
5	1.351	1.227
6	1.333	1.232
7	1.347	1.228
8	1.343	1.231
9	1.344	1.232
10	1.342	1.233
Mean	1.345	1.229

Table 2. Descriptive statistics of baseline and current measurement values

Parameter	Number of measurements	Minimum, mm	Maximum, mm	Mean	Standard deviation	Standard error of the mean	Variance	Skewness		Kurtosis	
								Statistic	Standard error	Statistic	Standard error
Baseline data	10	1.333	1.351	1.34460	0.004881	0.001543	0.000	-1.467	0.687	3.405	1.334
Current data	10	1.224	1.233	1.22930	0.003268	0.001033	0.000	-0.262	0.687	-1.552	1.334

**Fig. 8.** Histograms of significant distance measurements between prepared tooth 26 and antagonist tooth: *a*, baseline data (mean, 1.345 mm; SD, 0.005 mm; $n = 10$); *b*, current data (mean, 1.229 mm; SD, 0.003 mm; $n = 10$) (absolute units).

Comparative analysis with the Mann–Whitney U test (see Table 4) and Student's t -test for nonparametric samples (see Table 5) yielded asymptotic significance and two-sided significance values of 0 ($p < 0.05$). Thus, statistically significant differences were observed between baseline and current measurements.

The results demonstrated statistically significant differences between measurements taken over the specified period: the mean baseline value was 1.345 ± 0.005 mm, and the mean current value was 1.229 ± 0.003 mm. The difference between the two was 0.116 ± 0.002 mm, indicating displacement of the prepared tooth by 0.116 mm (116 μ m).

DISCUSSION

This study evaluated the negative consequences of discrepancies in the spatial position of a prepared tooth in the oral cavity compared with the laboratory

model. The findings demonstrated that, in the absence of a provisional restoration, such discrepancies are caused by displacement of the prepared tooth. The clinical case presented here, analyzed using digital technologies, allowed quantification of this displacement relative to the antagonist tooth. The measured displacement was 116 ± 2 μ m over a 24-day period.

Such an error cannot be compensated by the resilience of the periodontal ligament. To correct the occlusal discrepancy with the antagonist teeth, occlusal adjustment would be required, which alters the morphology of the occlusal surface previously modeled in its final form.

A second complication of prepared tooth displacement is compromised marginal adaptation of the crown, one of the most critical determinants of prosthodontic treatment quality. It is well established that intraoral adjustment of a prosthesis increases the cement space and reduces the precision of marginal adaptation achieved on the

Table 3. Comparative analysis by one-sample Kolmogorov–Smirnov Z test

Parameters		Baseline measurement values	Current measurement values
No.		10	10
Normal parameters ^{a, b}	Mean	1.34460	1.22930
	Standard deviation	0.004881	0.003268
	Magnitude	0.197	0.199
Differences of extremes	Positive	0.143	0.159
	Negative	–0.197	–0.199
Statistics for Kolmogorov-Smirnov Z test		0.623	0.628
Asymptotic significance (two-sided)		0.832	0.825

Note: a, comparison with normal distribution; b, estimated from data.

Table 4. Comparative analysis by Mann–Whitney U test

Ranks					Test statistics ^a	
	Measurement time	Number of measurements	Mean rank	Sum of ranks	Test	Measurement values by situation (absolute units)
Measurement values by situation	Baseline measurement	10	15.50	155.00	Mann–Whitney U test	0.000
	Current measurement	10	5.50	55.00	Wilcoxon W Test	55.000
	Total	20	—	—	Kolmogorov-Smirnov Z test	–3.787
					Asymptotic significance (two-sided)	0.000
					Exact significance [2*(one-sided significance)]	0.000b

Note: a, grouping variable: measurement time; b, not adjusted for dependencies.

Table 5. Baseline and current measurement values for Student's *t*-test on non-parametric samples

Equality of variances	Levene's test for equality of variances		<i>t</i> -test for equality of means				
	F	Significance	t	Statistical association	Significance (two-sided)	Mean difference ± standard error	95% confidence interval of the difference
Assumed	0.109	0.745	62.075	18.0	0.000	0.115300±0.001857	0.111398–0.119202
Not assumed	—	—	62.075	15.718	0.000	0.115300±0.001857	0.111357–0.119243

model. The global leader in metrology, Renishaw (UK), specifies a marginal discrepancy of 120 μm as the maximum threshold for reliable long-term function of fixed dental prostheses.

The clinical case described here, with 116 μm of tooth displacement during prosthesis fabrication, shows that forced intraoral adjustment of a single crown leads to marginal misfit and, subsequently, unreliable functioning of the fixed restoration. It is evident that, when multiple abutment teeth are involved in a single prosthesis, the cumulative error becomes even more critical.

Furthermore, it should be emphasized that when treatment is performed using CAD/CAM technologies, which generally demonstrate higher precision than conventional methods, intraoral adjustment of the prosthesis eliminates the primary advantage of digital dentistry over traditional techniques.

CONCLUSION

In the final clinical stage of fixed prosthodontic treatment, adjustment of the occlusal surfaces of crowns is often required because of premature contacts that cause occlusal interference. The key factor underlying this complication is the discrepancy between the spatial position of abutment teeth in the oral cavity and their representation in the laboratory model. This study demonstrated that such discrepancies result from displacement of the prepared tooth.

The clinical implications of these findings support the recommendation that fixed prosthodontic treatment

should be planned and completed within the shortest possible timeframe. If immediate fabrication of the definitive restoration is not feasible, the use of a provisional restoration is essential.

The measured displacement of the prepared tooth toward the antagonist teeth, assessed using digital dental models, indicates that a laboratory fabrication period of 24 days or longer without a provisional restoration is critical, as it leads to prosthetic misfit.

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Author contributions: K.V. Shtern: investigation, writing—original draft, writing—review & editing; E.A. Tyo: investigation, writing—original draft. Both authors affirm their compliance with the international ICMJE criteria (both authors made substantial contributions to the conceptualization, research, and manuscript preparation, and reviewed and approved the final version prior to publication).

Informed consent for publication: Written informed consent was obtained from the patient for the publication of personal data, including photographs (with faces obscured), in a scientific journal and its online version (signed on October 23, 2023).

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