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Principles of Categorization of Criteria for Assessing the Quality of Fixed Orthopedic Structures in Dynamics

Introduction. Over the past decade, the population's need for prosthetic dental care has increased significantly, driven by the high prevalence of included dentition defects, which in some regions of Ukraine exceeds 100%. Few scientific studies have focused on the expert assessment of the quality of fixed orthopedic restorative structures in dynamics to objectively evaluate their condition.

Aim. To categorize the criteria for the successful functioning of fixed orthopedic structures in dynamics by applying the developed algorithm of dispensary supervision.

Materials and Methods. Spearman's correlation analysis and cluster analysis were employed for statistical analysis. The clustering results were visualized as a dendrogram, with Euclidean distances calculated using the traditional distance formula. **Results.** To effectively and objectively monitor the condition of fixed restorations, an algorithm for examining patients was proposed, which included: 1. Patient questionnaire. 2. Professional examination by a dentist (dentist questionnaire). 3. Instrumental assessment of fixed restorations' mobility using a modified frequency resonance analysis method. 4. Additional diagnostic methods, particularly radiographic (X-ray) diagnostics.

Conclusion. In ranking diagnostic clusters to differentiate cement fixation disorders of fixed orthopedic structures of different types, clinically significant diagnostic clusters were identified, and the statistical significance of each was established.

Key words: prosthetic dentistry, fixed orthopedic structures, inlays, bridges, single crowns, loss of cement fixation of fixed orthopedic structures, dispensary supervision, statistical ranking.

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Принципи категоризації критеріїв оцінку якості незмінних ортопедичних конструкцій в динаміці

Вступ. За останнє десятиріччя суттєво зросла потреба населення в ортопедичному стоматологічному лікуванні, чому сприяє висока поширеність включених дефектів зубних рядів, яка в окремих регіонах України сягає понад 100%. Експертній оцінці якості незмінних ортопедичних відновлювальних конструкцій в динаміці з метою об'єктивізації стану присвячено незначна кількість наукових дослідження.

Мета – категоризація критеріїв успішності функціонування незмінних ортопедичних конструкцій в динаміці, шляхом застосування розробленого алгоритму диспансерного нагляду.

Матеріали та методи. Для проведення статистичного аналізу застосовувати методи кореляційного аналізу Спірмена та метод кластерного аналізу. Результат кластеризації візуалізували у вигляді дендрограми з обрахуванням евклідових відстаней – формула традиційної відстані між двома точками.

Результати. Для ефективного об'єктивного моніторингу стану незнімних відновлювальних конструкцій запропоновано алгоритм обстеження пацієнтів, котрий включав: 1. Анкетування пацієнтів. (Анкета для пацієнта); 2. Фаховий огляд стоматологом. (Анкета для стоматолога); 3. Апаратна перевірка рухомості незнімних відновлювальних конструкцій із застосуванням адаптованої оригінальної методики частотно-резонансного аналізу; 4. Додаткові методи діагностики, зокрема променеві (рентгендіагностика).

Висновок. При ранжуванні діагностичних кластерів для диференціації випадків порушення цементної фіксації незнімних ортопедичних конструкцій різних видів нами виокремлені клінічно-значущі діагностичні кластери та встановлена статистична вартість кожного кластера.

Ключові слова: ортопедична стоматологія, незнімні ортопедичні конструкції, вкладки, мостоподібні протези, одиночні коронки, втрата цементної фіксації незнімних ортопедичних конструкцій, диспансерний нагляд, статистичне ранжування.

Introduction. A retrospective analysis has shown that over the past decade, the need for orthopedic dental treatment has increased significantly. This is due to the high prevalence of included dentition defects, which in some regions of Ukraine reach almost 100% [1, 2]. Prosthetics with fixed denture structures have several advantages: they ensure complete rehabilitation of the biting function, characterized by a physiological method of chewing load transfer, and a high degree of restoration of chewing efficiency. Additionally, they ensure the aesthetic norm of a smile and white-pink aesthetics, with a short period of psychological and physiological adaptation for the patient [3, 4].

The evaluation of the functioning of fixed structures typically involves a dentist's examination, which includes a visual assessment of the structure, evaluation of chipped veneer material, changes in the bite, the presence of structural mobility, as well as gum inflammation. In some cases, X-ray diagnosis of root or crown caries, which support the fixed orthopedic structure, may also be conducted [5].

A limited number of scientific studies have been dedicated to the expert assessment of the quality of fixed orthopedic restorative structures over time, to objectify their condition. This area has not been thoroughly explored, making it an urgent and timely scientific task [6].

The aim of this study is to categorize the criteria for the successful functioning of fixed orthopedic structures over time by applying a developed algorithm for dispensary supervision.

Materials and Methods. The methods of correlation and cluster analysis were used for statistical analysis. **Method of Correlation Analysis:** Spearman's rank correlation coefficient is a non-parametric criterion for the relationship between two variables. It assesses how well the relationship between two variables can be described, even if the relationship is not linear. The correlation coefficient, g , ranges from -1 to 1. If $g \leq 1$, the Spearman correlation coefficient is positive; if $-1 \leq g \leq 0$, the Spearman correlation coefficient is negative. At a g value of $\pm 0.7-0.9$, with p (statistical significance), there is a strong relationship; at $g = \pm 0.5-0.7$, with p , there is an average level of relationship; and at $g = \pm 0.1-0.4$, there is a weak relationship. A Spearman's coefficient of zero indicates no correlation. **Cluster Analysis Method:** This method organizes the studied factors (attributes) into relatively homogeneous groups or clusters. It is a part of multivariate statistics. The primary purpose of cluster analysis is to identify groups of similar objects within the sample. Objects can be grouped in different ways, and in this study, the hierarchical clustering method, the nearest neighbor

method of single connection, and the Euclidean distance method were used. The clustering result can be visualized as a dendrogram. The Euclidean distance formula calculates the traditional distance between two points [7–12].

Results and Discussion. The quality assessment of fixed orthopedic structures was carried out in stages. Initially, an anamnesis was taken, which included an assessment of patient complaints, such as the presence of micromobility or vertical mobility of the structure, an unpleasant odor that worsens when chewing, and pain (Patient Questionnaire).

A questionnaire for the patient:

Mobility of the structure:

- Yes
- Vertical mobility is felt
- None

Unpleasant odor:

- Yes
- Yes, it increases during chewing
- None

Presence of painful sensations:

- Absent
- Discomfort when chewing
- Periodic pain when chewing
- Constant aching pain

The design is in the way and its presence in the mouth is annoying:

- Yes
- No
- Partially, periodically

The next step was a visual inspection of the structure by a dentist to detect chips in the facing material, changes in the bite, the presence of structural mobility, and various forms of gingivitis (hypertrophic, fibrous).

Questionnaire for the dentist:

Visual inspection of the fixed structure includes:

- Aesthetic component
- Color matching
- Harmony of colors
- Matching the color shade
- Customized color saturation
- Individual anatomical features of the teeth
- Architectonics of the neck area
- Reproduction of anatomical shape
- Correspondence of the crown equator
- Playback of contact points
- Matching analogues on the opposite side of the jaw
- Age-appropriate teeth shape
- Matching the shape of the face
- Matching of cutting edges and chewing surfaces
- Evaluation of the functioning

- Condition of the flushing space
- Position of the crown edge in the gingival sulcus
- The presence of continuous contact of the dentition
- Condition of occlusal contacts
- Contact of the crown edge with the tooth stump in the cervical area
- Surface quality of structures
- Roughness of the surface
- Matching gloss
- Porosity of the structure
- Presence of surface defects
- Condition of the crown margin in the cervical area (violation of integrity)

An important stage in checking the stability and quality of a fixed orthopedic structure is the hardware verification of its mobility using an adapted original method of frequency resonance analysis [13].

In the case of restoration of destroyed hard tissues of the tooth with intra-root cast stump inlays, radiological diagnosis of the condition of the tooth root is mandatory to diagnose the presence of root or crown caries, which support a fixed orthopedic structure. Therefore, to monitor the condition of fixed restorative structures, an algorithm for examining patients was proposed, which included:

1. Patient questionnaire (questionnaire for the patient) – Cluster 1
2. Professional examination by a dentist (questionnaire for the dentist) – Cluster 2
3. Hardware check of the mobility of fixed restorative structures using an adapted original method of frequency resonance analysis – Cluster 3
4. Additional diagnostic methods, including radiation – Cluster 4

When ranking the diagnostic clusters to differentiate cases of cement fixation disorders of fixed orthopedic structures of various types, clinically significant diagnostic clusters were identified, and the statistical value of each cluster was established. In each clinical case, the statistical significance of each of the four diagnostic clusters for diagnosis and treatment plans will vary. At the same time, Cluster 2 – examination by a doctor – is a priority in most clinical cases.

The following orthopedic restorative structures were selected for analysis:

1. Restorative inlays
2. Single metal-ceramic crowns
3. Metal-ceramic bridges
4. Single all-ceramic crowns

5. All-ceramic bridge prostheses
6. Intra-root cast stub inlays

Description of the evaluation of structures by clusters.

Diagnostic cluster 1 includes anamnesis and subjective data of patients based on the analysis of the developed questionnaire for patients (Table 1).

The overall assessment of the condition of the structure in diagnostic cluster 1 was assessed as follows: for each positive answer regarding discomfort, dissatisfaction with the structure in the patient, 1 point was assigned to his answer. Thus, answers such as no, no, or negative were given 0 points, and any other positive answer was given 1 point. For example: as a result of the patient's survey, according to the results of his answer, 3 points were obtained in cluster 1 – the design requires additional examination (Table 2).

If the patient responds positively to all items, the maximum number of points for the cluster is 4. In the case of negative answers, the total number of points is 0, which indicates the full functioning of the structure. If up to 75% of the symptoms are rated as "no" (absent), the total number of points is 1–2, suggesting that the functioning of the structure requires additional examination. In the case of 100% "yes" (present) answers, the total number of points is 3–4, indicating that the structure needs to be replaced.

As a result of the statistical analysis, the following patterns were established: a strong correlation was observed between the presence of odor and discomfort during chewing ($r=0.76$; $p=0.05$), as well as between odor and pain during chewing ($r=0.87$; $p=0.05$). The correlation indices also showed a moderate relationship between the symptoms of vertical tooth mobility and the presence of constant, aching pain ($r=0.69$; $p=0.05$).

Diagnostic cluster 2 was based on an objective dental examination by a dentist based on a questionnaire for the dentist. The cluster included an assessment of three components: aesthetic appearance, structural function, and structural surface quality.

The aesthetic component was evaluated according to the criteria listed in Table 3: for each answer of "no" out of the proposed "meets" or "does not meet" regarding discomfort, dissatisfaction with the design, 1 point was assigned to the answer.

The maximum possible number of points for an aesthetic complete design mismatch is 13 points.

Table 1

Indicators of subjective data of patients, cluster 1

Symptom	Cluster 1. Movability of the structure (1)			
Interpretation	No	Present	You can feel the vertical movement	-
Symptom	Cluster 1. Unpleasant odor (2)			
Interpretation	No	Present	Yes, reinforced during chewing	-
Symptom	Cluster 1. The design gets in the way, the presence in the mouth is annoying (3)			
Interpretation	No.	Yes.	Partially, periodically	-
Symptom	Cluster 1. Presence of pain (4)			
Interpretation	No	Discomfort when chewing	Periodic pain when chewing	Constant pain, aching
Evaluation of the answer	0 points	1 point	1 point	1 point

If the patient receives a score of 0, the structure is functioning properly; with a score of 1–8, the doctor and patient decide whether to replace the structure, as the aesthetic component may have different meanings for each patient.

For example, the color matching of the anterior teeth may be critical, requiring replacement, and, accordingly, if the color of the structure on the posterior teeth does not match, it may be acceptable to continue using the structure.

Accordingly, if the design mismatch is indicated in the range of 9–13 points, replacement of the prosthetic structure is recommended.

Assessment of the functioning of the structure. The criteria for assessing the functioning of fixed orthopedic restorative structures and their interpretation are given in Table 4.

Scoring: each answer of the proposed "Corresponds" or "Saved" in relation to the presented parameters was assigned a score of 0 points. The answer "no" was evaluated at 1 point.

The maximum possible number of points is 5. If the patient receives a score of 0, the functioning of the prosthetic structure does not require correction; 1–2 points – the functioning of the structure requires

Table 2

Example of patient's answers

Symptom	Cluster 1. Movability of the structure (1)			
Interpretation	No	Present	You can feel the vertical movement	-
Points.	0 points	1 point	1 point	-
Symptom	Cluster 1. Unpleasant odor (2)			
Interpretation	No	Present	Yes, reinforced during chewing	-
Points.	No, 0 points	Yes, 1 point	No, 0 points	-
Symptom	Cluster 1. The design gets in the way, the presence in the mouth is annoying (3)			
Interpretation	No.	Yes.	Partially, periodically	-
Number of points	No, 0 points	No, 0 points	Yes, 1 point	-
Symptom	Cluster 1. Presence of pain (4)			
Interpretation	No	Discomfort when chewing	Periodic pain when chewing	Constant pain, aching
Points.	No, 0 points	Yes, 1 point	No, 0 points	No, 0 points
The sum of points	0 points	2 points	1 point	0 points

Table 3

Indicators for assessing the aesthetic component of fixed orthopedic restorative structures

Parameters	Compliance	
1. Color matching	Answer.	No.
2. Harmony of colors	Answer.	No.
3. Matching the color shade	Answer.	No.
4. Individual color saturation	Answer.	No.
5. Individual anatomical features of your own teeth	Answer.	No.
6. Architectonics of the neck area	Saved	No.
7. Reproduction of anatomical shape	Recreated	No.
8. Correspondence of the crown equator	Answer.	No.
9. Playback of contact points	Answer.	No.
10. Correspondence to analogues on the opposite side of the jaw	Answer.	No.
11. Age appropriate teeth shape	Answer.	No.
12. Matching the shape of the face	Answer.	No.
13. Compliance of cutting edges and chewing surfaces.	Answer.	No.
Evaluation of the answer	0 points	1 point

Table 4

Indicators for assessing the functioning of fixed orthopedic restorative structures

Parameters	Compliance	
1. Condition of the flushing space	Answer.	No.
2. Position of the crown edge in the gingival sulcus	Answer.	No.
3. The presence of continuous contact of the dentition	Saved	No.
4. Condition of occlusal contacts	Answer.	No.
5. Contact of the crown edge with the tooth stump in the cervical region	Saved	No.
Assessment.	0 points	1 point

additional examination; 3–5 points – the structure needs to be replaced.

Assessment of surface quality. The criteria for assessing the surface quality of fixed orthopedic restorations and their interpretation are given in Table 5.

Scoring: For each answer from the proposed options "Corresponds," "Smooth," "Porous," "Present," or "Preserved" regarding the quality of the structure's surface, a score of 0 points was assigned. The answer "no" was evaluated at 1 point. The maximum possible number of points for assessing the functioning of a structure is 5. Indicators of 0–1 points correspond to the full functioning of the structure; 2–4 points indicate the need for additional surveys; and 4–5 points suggest that the structure needs to be replaced.

In cases where parameters 1–3 (gloss, roughness, porosity) are assessed negatively (1 point), the structure requires further monitoring. If parameters 4 (presence of surface defects) and 5 (violation of the integrity of the

crown edge in the cervical area) are negatively assessed, replacement of the structure is recommended.

A strong correlation was found between the presence of surface defects and impaired smoothness, gloss, or porosity ($r=0.87$; $p<0.05$).

Diagnostic cluster 3 includes data from hardware testing of the mobility of fixed restorative structures using an adapted original frequency resonance analysis technique. The results were presented in digital ISQ indices in the range of 1–100, with higher values indicating higher stability. The interpretation of the indicators is given in Table 6.

Diagnostic cluster 4 is based on the data from radiation methods for studying the violation of fixation of fixed restorative structures. Two answers are possible: "yes" (no retention loss) or "no" (there are retention loss).

For all other diagnostic signs related to the condition of fixed orthopedic structures, this cluster serves as additional confirmation or refutation of the results

Table 5

Indicators for assessing the surface quality of fixed orthopedic restorative structures

Parameters	Answer	No.
1. Roughness of the surface	Smooth	No.
2. Matching gloss	Answer.	No.
3. Porosity of the structure	Porous	No.
4. Presence of surface defects	Available	No.
5. Condition of the crown margin in the cervical area (violation of integrity)	Saved	No.
Assessment.	0 points	1 point

Table 6

Data on the hardware check of the mobility of fixed restorative structures

ISQ indicators	Interpretation	Algorithm of action
100–90	The fixation is fully preserved	-
90–70	Loss of fixation > 30%	additional examinations
70–55	Loss of fixation in the range of 30–50%	additional examinations, possible replacement
55–45	Loss of fixation in the range of 50–75%	replacement is recommended
45–25	Loss of fixation > 75%	needs to be replaced
< 25	Complete loss of fixation	replacement

from the previous diagnostic clusters, which assess the structure's condition. In many clinical cases, this cluster is an auxiliary diagnostic tool.

Conclusion. For effective objective monitoring of the condition of fixed restorations, an algorithm for examining patients was proposed, which included:

1. Patient questionnaire (patient questionnaire)
2. Professional examination by a dentist (dentist questionnaire)

3. Instrumental check of the mobility of fixed restorative structures using an adapted original method of frequency resonance analysis Additional diagnostic methods, including radiation (X-ray diagnostics)

In the process of ranking diagnostic clusters to differentiate cases of cement fixation disorders in various types of fixed orthopedic structures, we identified clinically significant diagnostic clusters and established the statistical value of each cluster.

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