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Original Article

Impact of dental operative microscopes on precision in minimally invasive dental restoration procedures

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Abstract: Objective: To evaluate the effect of dental operative microscopes on precision in minimally invasive dental restoration procedures. Methods: This retrospective analysis included patients who underwent minimally invasive dental restoration procedure at Nanjing Stomatological Hospital from March 2018 to December 2019. Patients were categorized into two groups, an observation group treated with microscope-guided provisional restorations, and a control group treated using conventional methods. Clinical indices, including implant survival rates over five years, were compared between the groups. Multivariate analysis was employed to identify independent risk factors for implant failure. Results: After treatment the observation group exhibited significantly lower labial vertical marginal discrepancies and absolute marginal discrepancies, as well as improved labial gingival indices and periodontal probing depths compared to the control group (all $P<0.001$). Additionally, the observation group scored significantly higher in efficiency, accuracy, and overall quality of tooth preparation (all $P<0.001$). Clinicians using microscopes demonstrated significantly lower mean Rapid Upper Limb Assessment scores, indicating reduced ergonomic strain ($P<0.001$). Higher age, worn tooth defects, poor oral hygiene, and non-use of a microscope were identified as independent risk factors for implant failure at the five-year mark. Conclusion: Dental operative microscopes significantly enhance the precision, efficiency, and ergonomic comfort in minimally invasive dental restorations for both clinicians and patients. Widespread adoption of this technology is strongly recommended.

Keywords: Microscope, precise minimally invasive dental restoration, value

Introduction

As the population ages, the prevalence of oral diseases among middle-aged and elderly individuals is increasing [1]. Pathological changes associated with aging, such as periodontitis and tooth loss, can lead to facial collapse, affecting speech, chewing, and occlusion [2, 3]. In severe cases, these conditions may also impair temporomandibular joint function, ultimately affecting facial aesthetics [2, 3].

Oral restoration employs physiologically adaptive devices to repair oral dysfunction caused by defects or deficiencies. Its goal is to restore oral functionality, enhance aesthetic appearance, and promote overall oral well-being [4]. Precision minimally invasive dental restoration, which leverages advanced digital technology and fine surgical skills, aims to minimize damage to dental and oral tissues while ensuring accurate restoration [5]. This technique, in comparison to traditional methods, reduces trauma and tissue removal, thus decreasing patient discomfort and speeding recovery [6].

Accurate and visually enhanced tools are crucial for executing precise minimally invasive dental restorations. The dental microscope, an advanced instrument in clinical medicine, significantly improves procedural visibility with its magnification capabilities and advanced lighting systems, offering an enlarged and detailed view during surgeries [7, 8]. Its high magnification and superior optical quality enable dentists to precisely identify and treat oral issues, reducing the risks associated with surgical interventions [9].

This study underscores the lack of comprehensive research on the impact of microscopes on clinical outcomes in precision minimally invasive dental restoration. By focusing on both patient outcomes and operator-related factors,

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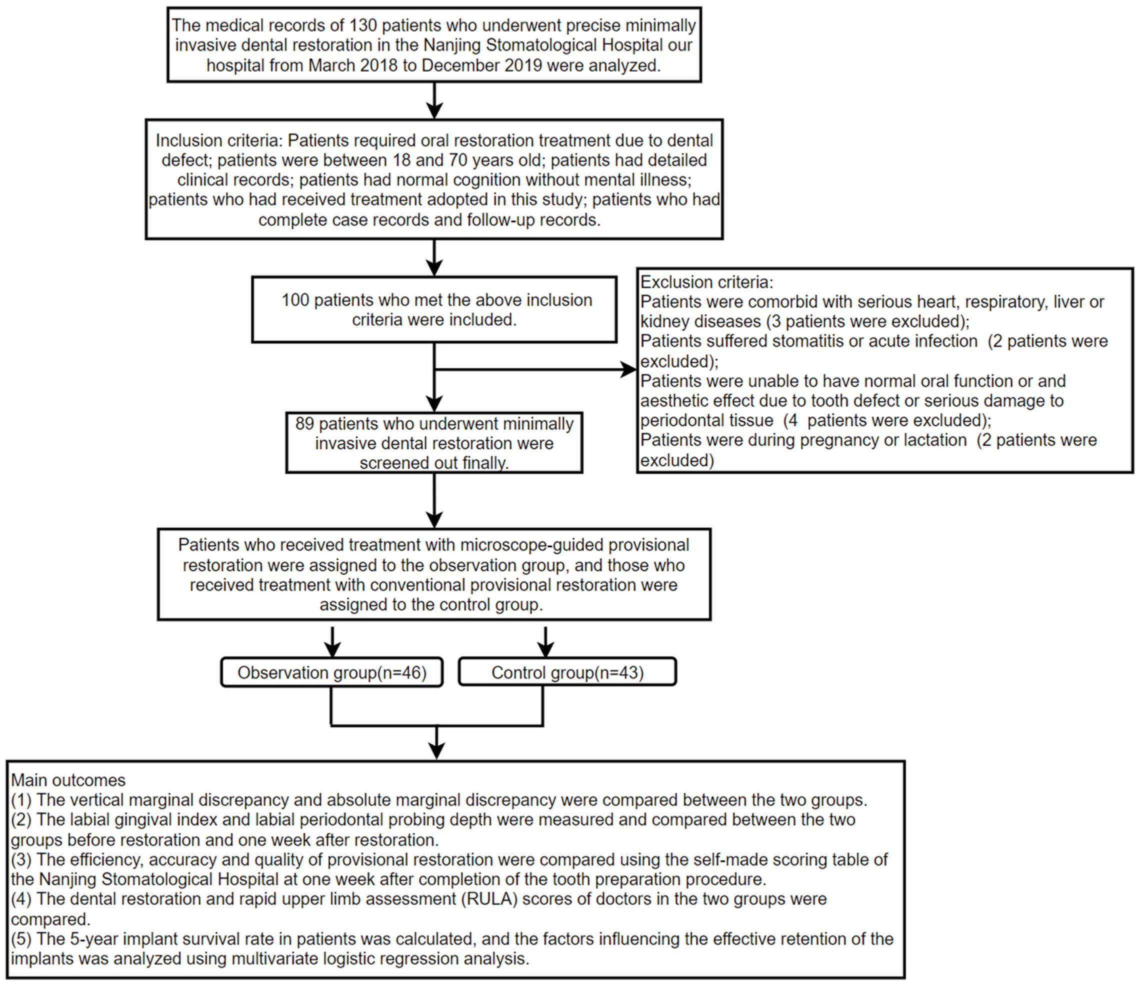

Figure 1. Flow chart for the study.

such as ergonomic benefits, our research aims to fill this gap. We seek to provide robust evidence of the benefits of using microscopes, addressing limitations found in previous studies and highlighting their values in enhancing the precision of dental restorations.

Materials and methods

General data selection

In this retrospective study, we analyzed data from 89 patients who underwent precise minimally invasive dental restoration at Nanjing Stomatological Hospital from March 2018 to December 2019. Patients were classified into two groups based on their treatment approaches. Those who received treatment with microscope-guided provisional restoration were assigned to the observation group (n=46), while those treated with conventional provisional restoration were categorized into the control group (n=43). The grouping process is illustrated in **Figure 1**. This study received approval from the Ethical Committee of Nanjing Stomatological Hospital.

Inclusion criteria: Patients included in the study required oral restoration for various dental defects such as dental caries, fractures, tooth loss, wear, and malformed teeth; patients aged between 18 and 70 years. Patients had detailed clinical records; patients had normal cognitive functions and no mental illnesses; patients had previously received the treatment approaches under investigation.

Exclusion criteria: Patients had severe comorbidities affecting the heart, lung, liver, or kidney functions; patients with stomatitis or acute infections; patients unable to maintain normal oral function or achieve aesthetic outcomes due to significant tooth defects or severe periodontal damage; pregnant or lactating patients.

Treatment protocol

Before treatment, all patients underwent X-ray examinations to assess dental health and positioning. During the treatment phase, microscope-guided provisional restoration was implemented for the observation group, while conventional provisional restoration was used for the control group. The same medical team treated both groups. Patients selected their treatment method based on personal factors such as cost and insurance coverage, and they were fully informed of each method's strengths and limitations.

Data collection and follow-up

Clinical data for both patients and clinicians were collected through the electronic medical record management system, which included demographics, type of dental defect, and other relevant indicators. Patients were followed annually via outpatient re-examinations and telephone interviews to monitor dental restoration outcomes up to five years post-procedure. Follow-up data collection focused on implant survival and oral hygiene practices.

Outcome measures

Primary outcome measures: Vertical and absolute marginal discrepancy: The vertical discrepancy was assessed by measuring the shoulder finish line on the labial side of the prepared tooth and the outermost point of the labial gingival margin of the porcelain crown using a dental preparation instrument in the first week post-restoration. These measurements were used to calculate the vertical and absolute marginal discrepancies for each patient.

Gingival index and periodontal probing depth: These were measured and compared between the groups both before restoration and one week post-restoration.

Efficiency, accuracy, and quality of provisional restoration: Evaluated using a scoring table developed by Nanjing Stomatological Hospital. Each aspect was rated out of 10 points, with higher scores indicating better outcomes.

Secondary outcome measures: (1) Clinical baseline data: Baseline data were assessed and compared between the two groups to ensure initial comparability. (2) Dental restoration and Rapid Upper Limb Assessment (RULA) scores: The ergonomic impact on dentists during procedures was evaluated using RULA scores, which assess posture, strength load, and muscle use in arms, wrists, neck, torso, and legs. Each component was scored based on predetermined criteria, with final composite scores ranging from 1 to 7.

Five-year implant survival rate: The long-term success of the implants was assessed by calculating the 5-year survival rate, with contributing factors analyzed using multivariate logistic regression.

Statistical analysis

Data analysis was performed using SPSS20.0 (SPSS Co., Ltd., Chicago, USA). Descriptive data were expressed as percentage (%), and analyzed using the chi-square test, presented as χ^2. Measurement data following a normal distribution were compared using independent t-tests between groups, while paired t-tests were used within each group to assess changes over time. Multivariate logistic regression analysis was utilized to explore factors influencing implant retention. A p-value <0.05 was considered statistically significant.

Results

Comparison of baseline data

No significant differences were observed between the groups in terms of sex, age, duration, type and location of dental defects, teeth cleaning habits, smoking history, and alcohol use (all $P>0.05$, **Table 1**).

Comparison of labial gingival marginal discrepancy

Post-treatment, the observation group exhibited significantly lower labial vertical marginal discrepancy and absolute marginal discrepan-

Table 1. Comparison of baseline data

	Observation group (n=46)	Control group (n=43)	X^2/t	P
Sex			0.510	0.475
Male	27 (58.70)	22 (51.16)		
Female	19 (41.30)	21 (48.84)		
Age (years)	47.52±7.31	46.44±6.84	0.718	0.474
Duration of tooth defect (years)	2.37±0.61	2.12±0.73	1.757	0.082
Type of tooth defect			0.568	0.451
Wedge-shaped teeth defect	24 (52.17)	19 (44.19)		
Wear-type teeth defect	22 (47.83)	24 (55.81)		
Location of teeth defect			0.457	0.499
Anterior teeth area	14 (30.43)	16 (37.21)		
Posterior area	32 (69.57)	27 (62.79)		
Tooth cleaning method			0.163	0.687
Correct	37 (80.43)	36 (83.72)		
Incorrect	9 (19.57)	7 (16.28)		
Smoking history			0.215	0.643
Yes	16 (34.78)	17 (39.53)		
No	30 (65.22)	26 (60.47)		
Alcohol use			0.499	0.480
Yes	9 (19.57)	6 (13.95)		
No	37 (80.43)	37 (86.05)		
Comorbidities (hypertension or diabetes)			0.069	0.793
Yes	14 (30.43)	12 (27.91)		
No	32 (69.57)	31 (72.09)		
Treatment history related to oral defects			0.182	0.670
Yes	10 (21.74)	11 (25.58)		
No	36 (78.26)	32 (74.42)		

Table 2. Comparison of labial gingival marginal discrepancy

	Vertical marginal discrepancy	Absolute marginal discrepancy
Observation group (n=46)	45.58±11.01	51.36±9.34
Control group (n=43)	84.36±16.24	97.36±15.18
t	13.263	17.342
P value	<0.001	<0.001

cy compared to the control group (both P<0.001, **Table 2**).

Comparison of labial gingival index and periodontal probing depth

Initially, there were no significant differences between the groups in labial gingival index and periodontal probing depth (both P>0.05). However, post-treatment, the observation group showed significantly reduced labial gingival index and periodontal probing depth compared to the control group (both P<0.001, **Table 3**).

Comparison of tooth preparation indices

Observations of tooth preparation indices indicated that the observation group achieved significantly higher scores in efficiency, accuracy, and quality of tooth preparation compared to the control group (both *P<0.001*, **Table 4**).

Comparison of RULA scores

RULA scores were significantly lower for doctors in the observation group than those in the control group, indicating better ergonomic practices (P<0.001, **Table 5**).

Table 3. Comparison of labial gingival index and periodontal probing depth

	Gingival index		Periodontal probing depth (mm)	
	Before treatment	After treatment	Before treatment	After treatment
Observation group (n=46)	0.67±0.13	0.38±0.08*	1.86±0.19	1.56±0.11*
Control group (n=43)	0.65±0.11	0.50±0.05#	1.90±0.17	1.74±0.08#
t	0.781	8.417	1.044	8.778
P value	0.437	<0.001	0.299	<0.001

Notes: *indicates P<0.001 vs. the observation group before treatment. #indicates P<0.001 vs. the control group before treatment.

Table 4. Comparison of tooth preparation indexes

	Efficiency of tooth preparation	Accuracy of preparation	Quality of preparation
Observation group (n=46)	9.35±0.59	9.21±0.84	9.32±0.61
Control group (n=43)	7.72±0.38	7.94±0.62	8.11±0.47
t	15.376	8.069	10.430
P	<0.001	<0.001	<0.001

Table 5. Comparison of RULA scores

	Observation group (n=46)	Control group (n=43)
RULA score	3.35±0.24	5.95±0.42
t	36.152	
P	<0.001	

RULA: Dental Restoration and Rapid Upper Limb Assessment.

Univariate analysis of the factors influencing 5-year implant survival

Among the 124 implants analyzed from 89 patients, 109 were successfully retained after five years, yielding a survival rate of 87.90%. Univariate analysis suggested that age, type of tooth defect, location of tooth loss, oral hygiene practices, and use of a microscope during prosthetic preparation may influence implant retention (**Table 6**).

Multivariate analysis

Further multivariate analysis identified higher age, worn tooth defects, poor oral hygiene, and non-use of a microscope during prosthetic preparation as independent risk factors for implant failure (**Table 7**).

Discussion

The prevalence of oral diseases is increasing rapidly, highlighting the significance of effective oral restoration treatments in stomatology [10]. Achieving optimal gingival margin closure is crucial in dental preparations to ensure the effectiveness and comfort of dental restorations [11, 12]. Inadequate closure can lead to gaps at the gingival margin, fostering an environment conducive to bacterial accumulation. Over time, this can trigger various periodontal inflammatory responses and potentially damage periodontal tissues [13, 14].

In this study, the observation group demonstrated significantly lower labial vertical marginal discrepancy and absolute marginal discrepancy than the control group after treatment, underscoring the effectiveness of microscopes in precise minimally invasive dental restoration. The use of microscopes during dental procedures allows dentists to enhance tooth preparation, thereby preserving more healthy dental tissue and minimizing damage [15]. Furthermore, the observation group showed significantly lower labial gingival index and labial periodontal probing depth compared to the control group. This improvement likely results from the enhanced adaptation and marginal quality of restorations facilitated by microscope-guided procedures, which in turn reduce gingival inflammation and periodontal tissue stimulation.

Quantitative evaluation of operational effectiveness, accuracy, and quality in the restoration process helps both dentists and patients better understand the treatment outcomes [16]. This study revealed that the observation group achieved higher scores in efficiency, accuracy, and quality of tooth preparation, illustrating the benefits of microscope-guided precision in dental restoration. Enhanced vision and clarity provided by microscopes contribute to

Table 6. Univariate analysis

Factor	Implant survival (n=109)	Failure (n=15)	X^2/t	*P*-value
Sex			0.724	0.395
Male	60 (55.05)	10 (66.67)		
Female	49 (44.95)	5 (33.33)		
Age (Y)	47.15±6.67	53.13±7.01	3.236	0.002
Age of missing teeth (years)	2.25±0.68	2.40±0.63	0.808	0.421
Types of tooth defects			6.480	0.011
Wedge-shaped tooth defect	60 (55.05)	3 (20.00)		
Worn tooth defect	49 (44.95)	12 (80.00)		
Tooth loss location			4.831	0.028
Anterior dental region	34 (31.19)	9 (60.00)		
Posterior dental region	75 (68.81)	6 (40.00)		
Oral hygiene practices			4.848	0.028
Correct	93 (83.78)	9 (60.00)		
Incorrect	18 (16.22)	6 (40.00)		
Smoking history			1.928	0.165
Yes	38 (34.86)	8 (53.33)		
No	71 (65.14)	7 (46.67)		
Alcohol use			0.744	0.388
Yes	19 (17.43)	4 (26.67)		
No	90 (82.57)	11 (73.33)		
Use of microscope to prepare the prosthesis			4.835	0.028
Yes	62 (56.88)	4 (26.67)		
No	47 (43.12)	11 (73.33)		

Table 7. Multivariate analysis

Factor	B	*P*-value	Exp (B)
Age	0.244	0.001	1.276 (1.103-1.477)
Types of tooth defects	-2.231	0.012	0.107 (0.019-0.606)
Tooth loss location	-0.189	0.804	0.828 (0.186-3.684)
Oral hygiene practices	-2.341	0.006	0.096 (0.018-0.504)
Use of a microscope used to prepare the prosthesis	-2.522	0.005	0.080 (0.014-0.471)

more accurate and efficient dental procedures, allowing dentists to make precise adjustments in preparation shape, marginal quality, and adaptability [17, 18].

Additionally, this study noted significantly lower RULA scores among dentists in the observation group compared to those in the control group, indicating improved working posture and ergonomic alignment. The magnification and illumination provided by microscopes enable dentists to better observe and address oral issues, adjust their posture, and experience less muscle fatigue and discomfort in the upper limbs [19-21].

The 5-year implant survival rate observed was 87.90%. Multivariate analysis identified higher age, the presence of worn tooth defects, poor oral hygiene, and non-use of a microscope for prosthetic preparation as independent risk factors for implant failure.

This research underscores the significant role of microscopes in enhancing the precision, efficiency, and ergonomic benefits of minimally invasive dental restoration, advocating for their wider adoption in clinical practice.

The identification of independent risk factors contributing to implant failure provides crucial insights for enhancing the success rates of dental implant procedures. First, the association between higher age and implant failure underscores the necessity for tailored treatment planning for older patients. Age-related factors such as diminished bone density and compromised healing abilities may elevate the risk of implant failure [22, 23]. It is advisable for dentists to consider these factors when assessing the suitability of implant placement in this demographic and to implement strategies to enhance implant stability and longevity.

The identification of worn tooth defects as a risk factor highlights the importance of a comprehensive assessment and treatment of existing dental conditions prior to implant placement. Patients with worn tooth defects might face challenges like occlusal instability or bruxism, which can adversely affect the success of dental implants [23]. Addressing these conditions with appropriate treatment strategies can significantly enhance implant success rates.

Poor oral hygiene is well-recognized as a potential risk factor for implant failure [24]. It can lead to the accumulation of plaque and bacteria around the implant site, resulting in peri-implantitis and potential implant failure. Emphasizing patient education on proper oral hygiene practices and regular professional maintenance is critical to minimizing these risks [25, 26].

Moreover, non-use of a microscope for prosthetic preparation has emerged as an independent risk factor for implant failure. The use of microscopes in dental procedures enhances visualization, precision, and accuracy, leading to better-fitting restorations and improved long-term implant outcomes. Dental professionals should be encouraged to integrate such advanced technologies into their practice to optimize treatment results.

This study also acknowledges certain limitations. The influence of dental restoration extends beyond prosthetic materials and devices; it also depends on the dentists' skills and experience. The retrospective nature of the analysis and the limited follow-up period restrict our understanding of long-term patient outcomes, introducing potential biases. Additionally, the small sample size of failed cases relative to the number of variables increases the risk of spurious associations, highlighting the need for cautious interpretation of the results and further validation with larger, prospective randomized controlled trials. The observed wide range of 95% confidence intervals also suggests model instability.

In conclusion, the utilization of microscopes in precise minimally invasive dental restoration has demonstrated positive clinical outcomes, playing a critical role in enhancing the efficiency and quality of provisional restorations and providing ergonomic benefits for dentists. Therefore, the widespread adoption and promotion of microscopes in dental practices are highly recommended due to their significant clinical values.

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Disclosure of conflict of interest

None.

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References

[1] Kanasi E, Ayilavarapu S and Jones J. The aging population: demographics and the biology of aging. Periodontol 2000 2016; 72: 13-18.

[2] Yan GLK, Tan MN, Wong ML, Tay CM and Allen PF. Functional dentition, chronic periodontal disease and frailty in older adults-a narrative review. Int J Environ Res Public Health 2022; 20: 502.

[3] González-Chávez SA, Pacheco-Tena C, Campos Torres RM, Quiñonez-Flores CM, Reyes-Cordero G and Caraveo Frescas TJ. Temporomandibular and odontological abnormalities in patients with rheumatoid arthritis. Reumatol Clin (Engl Ed) 2020; 16: 262-271.

[4] Arola DD, Gao S, Zhang H and Masri R. The tooth: its structure and properties. Dent Clin North Am 2017; 61: 651-668.

[5] Leal SC, Dame-Teixeira N, Barbosa CB, Kominami PAA, Raposo F, Nakagawa EMT and Banerjee A. Minimum intervention oral care: defining the future of caries management. Braz Oral Res 2022; 36: e135.
[6] Anoixiadou S, Parashis A and Vouros I. Minimally invasive non-surgical technique in the treatment of intrabony defects-a narrative review. Dent J (Basel) 2023; 11: 25.
[7] Wooster TJ, Loussert-Fonta C, Ash A, Stoudmann R, Hass R and Colijn I. Novel oral microscope gives mechanistic insights into colloidal drivers of friction in oral biofilms. J Colloid Interface Sci 2023; 646: 426-437.
[8] Setzer FC and Kratchman SI. Present status and future directions: surgical endodontics. Int Endod J 2022; 55 Suppl 4: 1020-1058.
[9] Bud M, Zlăvog M, Jitaru Ş, Korkut B, Spataru S and Delean A. The outcome of direct composite restorations using the dental operating microscope. Med Pharm Rep 2021; 94: 477-482.
[10] Santos-Silva AR, Lopes MA, Pedroso CM, Ribeiro ACP, Fonseca FP, Brandão TB, Gueiros LAM, Rocha AC, Pires FR, Miranda ÁA, Júnior HM, Alves FA, Marcucci M, Lemos CA, Sugaya NN, Marcucci G, Carrard VC, Martins MD, Cardoso AS and Migliorati CA. Oral medicine (stomatology) in Brazil: the first 50 years and counting. Oral Surg Oral Med Oral Pathol Oral Radiol 2022; 134: 57-64.
[11] Takeuchi Y, Koizumi H, Furuchi M, Sato Y, Ohkubo C and Matsumura H. Use of digital impression systems with intraoral scanners for fabricating restorations and fixed dental prostheses. J Oral Sci 2018; 60: 1-7.
[12] Mugri MH, Sayed ME, Nedumgottil BM, Bhandi S, Raj AT, Testarelli L, Khurshid Z, Jain S and Patil S. Treatment prognosis of restored teeth with crown lengthening vs. deep margin elevation: a systematic review. Materials (Basel) 2021; 14: 6733.
[13] Shah R, Thomas R and Mehta DS. Neutrophil priming: Implications in periodontal disease. J Indian Soc Periodontol 2017; 21: 180-185.
[14] Wada A, Murakami K, Ishikawa Y, Amoh T, Hirao K, Hosokawa Y, Hinode D, Miyake Y and Yumoto H. Anti-inflammatory and protective effects of juncus *effusus* L. water extract on oral keratinocytes. Biomed Res Int 2022; 2022: 9770899.
[15] Yadav VS, Salaria SK, Bhatia A and Yadav R. Periodontal microsurgery: reaching new heights of precision. J Indian Soc Periodontol 2018; 22: 5-11.
[16] Wang Y, Bäumer D, Ozga AK, Körner G and Bäumer A. Patient satisfaction and oral health-related quality of life 10 years after implant placement. BMC Oral Health 2021; 21: 30.
[17] Bud M, Jitaru S, Lucaciu O, Korkut B, Dumitrascu-Timis L, Ionescu C, Cimpean S and Delean A. The advantages of the dental operative microscope in restorative dentistry. Med Pharm Rep 2021; 94: 22-27.
[18] Bud MG, Pop OD and Cîmpean S. Benefits of using magnification in dental specialties - a narrative review. Med Pharm Rep 2023; 96: 254-257.
[19] Pazos JM, Fernandes AFRM, Verri ED, Gomes GGC, Regalo SCH and Garcia PPNS. Magnification in preclinical procedures: effect on muscle activity and angular deviations of the neck and trunk. PeerJ 2024; 12: e17188.
[20] Pazos JM, Regalo SCH, de Vasconcelos P, Campos JADB and Garcia PPNS. Effect of magnification factor by Galilean loupes on working posture of dental students in simulated clinical procedures: associations between direct and observational measurements. PeerJ 2022; 10: e13021.
[21] Pazos JM, Wajngarten D, Dovigo LN and Garcia PPNS. Implementing magnification during preclinical training: effects on procedure quality and working posture. Eur J Dent Educ 2020; 24: 425-432.
[22] Boboeva O, Kwon TG, Kim JW, Lee ST and Choi SY. Comparing factors affecting dental-implant loss between age groups: a retrospective cohort study. Clin Implant Dent Relat Res 2021; 23: 208-215.
[23] Zhou N, Dong H, Zhu Y, Liu H, Zhou N and Mou Y. Analysis of implant loss risk factors especially in maxillary molar location: a retrospective study of 6977 implants in Chinese individuals. Clin Implant Dent Relat Res 2019; 21: 138-144.
[24] Soldo M, Matijević J, Malčić Ivanišević A, Čuković-Bagić I, Marks L, Nikolov Borić D and Jukić Krmek S. Impact of oral hygiene instructions on plaque index in adolescents. Cent Eur J Public Health 2020; 28: 103-107.
[25] Ribeiro YJS, Ferreira LG, Nelson-Filho P, Arnez MFM and Paula-Silva FWG. Influence of digital media in the oral health education of mother-child pairs: study protocol of a parallel double-blind randomized clinical trial. Trials 2022; 23: 639.
[26] Raison MH, Corcoran R, Burnside G and Harris R. Oral hygiene behaviour automaticity: are toothbrushing and interdental cleaning habitual behaviours? J Dent 2020; 102: 103470.