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SUMMARY

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ORIGINAL ARTICLES

CASE REPORTS

LITERATURE REVIEWS

ORIGINAL ARTICLE

USE OF BRAILLE IN ORAL HEALTH EDUCATION FOR THE VISUALLY IMPAIRED PERSON - SYSTEMATIC REVIEW AND META-ANALYSIS

USO DO BRAILE NA EDUCAÇÃO EM SAÚDE BUCAL PARA DEFICIENTES VISUAIS – REVISÃO SISTEMÁTICA E META-ANÁLISE

Gabriel Oliveira Figueiredo[1], Marcela Baraúna Magno[2,3]

ABSTRACT

Objective: To evaluate the use of Braille, alone or in combination, as a method of oral health education for visually impaired patients. **Methods:** A search strategy was carried out in 6 databases and in the grey literature retrieving studies published until February 2021. Following the acronym PICOS, randomized controlled clinical trials (S) that evaluated people with visual impairment (P), who received oral hygiene instruction with educational methods containing Braille alone or together (I), compared to educational methods without Braille (C), and evaluated their influence on oral hygiene indices (O) were considered eligible. The risk of bias of the studies considered eligible was assessed using the ROB.2 and meta-analyses were performed to compare the different methods in relation to gingival and plaque index. The certainty of the evidence was assessed (GRADE). **Results:** A total of 9 articles were included in the present review and 5 in the meta-analysis. All studies were rated as 'some concern' regarding risk of bias. Braille, when used alone, is shown to be inferior to other methods ($p<0.05$); when used in association with audio or audio-tactile-performance (ATP) it is shown to be similar to ATP ($p>0.05$), and when implemented together with ATP it is shown to be superior to techniques without Braille ($p<0.05$). The certainty of the evidence ranged from very low to moderate. **Conclusion:** Braille used alone was less effective, whereas multisensory methods including Braille and ATP are more effective when compared to oral health education methods without Braille.

Keywords: Vision disorders, Oral health, Oral health education.

RESUMO

Objetivo: Avaliar o uso do braile, de forma isolada ou conjunta, como método de educação em saúde bucal para pacientes com deficiência visual. **Métodos:** Uma estratégia de busca foi realizada em 6 bases de dados e na literatura cinzenta resgatando os estudos publicados até fevereiro de 2021. Seguindo o acrônimo PICOS, foram considerados elegíveis estudos clínicos controlados e randomizados (S) que avaliassem pessoas com deficiência visual (P), que receberam instrução de higiene oral com métodos educativos contendo braile de forma isolada ou conjunta (I), comparados a métodos educativos sem braile (C), e avaliaram sua influência em índices de higiene oral (O). O risco de viés dos estudos considerados elegíveis foi avaliado através da ferramenta ROB.2 e meta-analises foram realizadas para comparar os diferentes métodos em relação ao índice gengival e de placa. A certeza da evidência foi avaliada (GRADE). **Resultados:** No total, 9 artigos foram incluídos na presente revisão e 5 na meta-análise. Todos os estudos foram classificados como 'alguma preocupação' em relação ao risco de viés. O braile, quando utilizado de forma isolada, mostra-se inferior aos demais métodos ($p<0,05$); quando usado associado ao áudio ou áudio-tátil-performance (ATP) mostra-se semelhante ao ATP ($p>0,05$), e quando implementado juntamente com o ATP, mostra-se superior a técnicas sem braile ($p<0,05$). A certeza da evidência variou de muito baixa a moderada. **Conclusão:** O braile utilizado de forma isolada apresentou-se menos eficiente, enquanto métodos multissensoriais, incluindo o braile e ATP, são mais eficientes quando comparados a métodos de educação em saúde bucal sem braile.

Palavras-chave: Transtornos da visão, Saúde bucal, Educação em saúde bucal.

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INTRODUCTION

According to 2018 data from the Brazilian Institute of Geography (IBGE), there are an estimated 22,500- 26,700 children up to 12 years old who are blind in Brazil, and visual impairment can range from low vision to blindness (educa.ibge.gov.br). According to the 10th revision of the International Statistical Classification of Diseases and Health Problems (CID-10), visual impairment may be classified into grades/categories, in which is considered light visual impairment or absence of visual impairment (category 0) when the value of visual acuity is equal to or greater than 0.3; moderate visual impairment (category 1) when the value is less than 0.3 and greater than or equal to 0.1; severe visual impairment (category 2) when the value is less than 0.1 and greater than or equal to 0.05; blindness (category 3, 4 and 5), when the value is less than 0.05 up to no light perception (1). Visual impairment can make people unable to lead an autonomous life, requiring the help of their families and, unfortunately, oral health is often neglected (2).

Regarding oral hygiene instruction (OHI) for this population, it is necessary to consider several tools used in day-to-day social dentistry. The use of plaque revealing, to allow the patient to visualize areas of impaired brushing, plays, videos, and informative brochures are excluded from this scenario (3). Visually impaired children have poorer oral hygiene and a higher rate of caries when compared to normally sighted children (4).

Braille, a tactile writing medium, is shown to be a useful tool to convey various information about oral health education for people living with low vision and blindness. Two studies (4,5) have reported that Braille and auditory media are effective in motivating and educating visually impaired patients, while other studies report that a multisensory approach is more effective than a unisensory approach (6,7). Thus, gaps remain open in the literature about the best form of oral health education for the visually impaired.

Considering that children with visual impairment and blindness tend to have a greater oral health impairment (3,4) , that many dentists do not feel qualified to care for them (4) and that there is no consensus in the literature as to the superiority of Braille in oral health education techniques, the aim of this study was to compare the efficacy of oral health education methods with Braille in relation to methods without Braille in people with visual impairment or blindness, by systematic review of the literature. The oral health education methods could be applied alone or in association (multisensorial methods).

METHODOLOGY

An electronic search was performed in the electronic databases *PubMed, Scopus, Embase, Web of Science, Cochrane Library, Lilacs (via Virtual Health Library) and OpenGrey* in February 2021, using mesh terms and free terms related to the theme of the present review. No language or publication date restrictions were placed. Table 1 shows the search strategy performed in each database.

Eligibility and study selection criteria

Two authors (G.O.F. and M.B.M.) independently evaluated the title and abstract of all articles retrieved from the databases for eligibility criteria for this systematic review. The predefined eligibility criteria were based on the acronym PICO (8): randomized controlled clinical trials that evaluated patients with visual impairment or total blindness (P), who received OHI with educational methods containing Braille alone or in combination (I), compared to educational methods without Braille (C), and their influence on oral hygiene (O). Non-randomized studies, studies that did not include Braille as an educational method, review articles, letters to the editor, single-arm studies (before and after), and observational studies were excluded from this review. Any disagreement among authors was resolved by consensus.

When the title and abstract did not provide enough information, the full text was retrieved and analyzed for a final decision regarding its inclusion or exclusion.

Data Extraction

All studies considered eligible were analyzed and characteristics such as authors, year, country of origin, study design, exclusion criteria, population (age and blindness level), comparison groups (with and without Braille), time of application of the educational method, follow-up time and evaluation periods, indexes and/or outcomes evaluated, and loss in the groups were tabulated and presented descriptively.

Bias Risk Analysis

Methodological quality and risk of bias were assessed using the *Cochrane* Risk of Bias Tool for Randomized Clinical Trials (RoB 2.0). For each item, scores representing low, uncertain or high risk of bias were accepted. This tool assesses the presence of bias in five domains: during the randomization process; deviations in intended interventions; missing outcome data; during outcome measurement; and in the reporting of results. Each domain, as well as the final judgment about each study's risk of bias, was rated as "low," "high," or "some concerns." Two examiners (G.O.F. and M.B.M.) performed the

TABLE 1. SEARCH STRATEGY (PERFORMED IN FEBRUARY 2021)

Pubmed (17)	#1 - dental caries[MeSH Terms] OR dental decay[Title/Abstract] OR “white spot”[thiab] OR “white spots”[thiab] OR Demineral*[thiab] OR ECC[thiab] OR DMF[thiab] OR DMFT[thiab] OR “Decayed, Missing, and Filled Teeth”[tiab] OR Deft[tiab] OR DMFS[tiab] OR ICDAS[tiab] OR NYVAD[tiab] OR carious[Title/Abstract] OR carie*[tiab] OR oral hygiene[MeSH Terms] OR oral hygiene[Title/Abstract] OR oral health[MeSH Terms] OR oral health[tiab] OR Hygiene, Oral[tiab] OR Dental Hygiene[tiab] OR Hygiene, Dental[tiab] OR Plaque Inde*[tiab] OR Gingival inde*[tiab] OR probing depth[tiab] OR bleeding on prob*[tiab] OR marginal bone[tiab] OR Patient Hygiene Performance index[tiab] OR biofilm[tiab] #2 - braille[thiab] #3 - visually impaired persons [MeSH Terms] OR visually impaired[thiab] OR blindness[MeSH Terms] OR blind*[thiab] OR Impaired Visually[thiab] Search #1 and #2 and #3
Scopus (19)	#1 INDEXTERMS ({dental caries} OR {oral hygiene} OR {oral health}) OR TITLE-ABS-KEY ({dental decay} OR {white spot} OR {white spots} OR demineral* OR ecc OR dmf OR dmft OR {decayed, Missing, and Filled Teeth} OR deft OR dmfs OR icdas OR nyvad OR carious OR carie* OR {oral hygiene} OR {oral health} OR {Hygiene, Oral OR Dental Hygiene} OR {Hygiene, Dental} OR {Plaque Index} OR {Gingival index} OR {probing depth} OR {bleeding on prob} OR {bleeding on probing} OR {marginal bone} OR {Patient Hygiene Performance index} OR biofilm) #2 TITLE-ABS-KEY (braille) #3 INDEXTERMS ({visually impaired persons} OR blindness} OR TITLE-ABS-KEY ({visually impaired} OR blind* OR {Impaired Visually}) Search #1 and #2 and #3
Web Of Science (13)	#1 TS=(“dental decay” OR “white spot” OR “white spots” OR Demineral* OR ECC OR DMF OR DMFT OR “decayed, Missing, and Filled Teeth” OR Deft OR DMFS OR ICDAS OR NIVAD OR carious OR carie* OR “oral hygiene” OR “oral health” OR “Hygiene, Oral OR Dental Hygiene” OR “Hygiene, Dental” OR “Plaque Index” OR “Gingival index” OR “probing depth” OR “bleeding on prob” OR “bleeding on probing” OR “marginal bone” OR “Patient Hygiene Performance index” OR biofilm) #2 TS=(braille) #3 TS=(“visually impaired” OR blind* OR “Visually Impaired”) Search #1 and #2 and #3
Cochrane (11)	#1 MeSH descriptor: [Dental Caries] explode all trees #2 MeSH descriptor: [Oral Hygiene] explode all trees #3 MeSH descriptor: [Oral Health] explode all trees #4 (“dental decay” OR “white spot” OR “white spots” OR Demineral* OR ECC OR DMF OR DMFT OR “decayed, Missing, and Filled Teeth” OR Deft OR DMFS OR ICDAS OR NIVAD OR carious OR carie* OR “oral hygiene” OR “oral health” OR “Hygiene, Oral OR Dental Hygiene” OR “Hygiene, Dental” OR “Plaque Index” OR “Gingival index” OR “probing depth” OR “bleeding on prob” OR “bleeding on probing” OR “marginal bone” OR “Patient Hygiene Performance index” OR biofilm):ti,ab,kw #5 #1 OR #2 OR #3 OR #4 #6 (braille):ti,ab,kw #7 MeSH descriptor: [Visually Impaired Persons] explode all trees #8 MeSH descriptor: [Blindness] explode all trees #9 (‘visually impaired’:ti,ab,kw OR blind*:ti,ab,kw OR ‘Visually Impaired’):ti,ab,kw #10 #7 OR #8 OR #9 #11 #5 AND #6 AND #10
Embase (10)	#1 ‘dental caries’/mj OR ‘mouth hygiene’/mj OR ‘oral hygiene index’/mj OR ‘oral health status’/mj OR ‘dental decay’:ti,ab,kw OR ‘white spot’:ti,ab,kw OR ‘white spots’:ti,ab,kw OR demineral*:ti,ab,kw OR ecc:ti,ab,kw OR dmf:ti,ab,kw OR dmft:ti,ab,kw OR ‘decayed, missing, and filled teeth’:ti,ab,kw OR deft:ti,ab,kw OR dmfs:ti,ab,kw OR icdas:ti,ab,kw OR nivad:ti,ab,kw OR carious:ti,ab,kw OR carie*:ti,ab,kw OR ‘oral hygiene’:ti,ab,kw OR ‘oral health’:ti,ab,kw OR ‘hygiene,:ti,ab,kw oral:ti,ab,kw OR dental hygiene’:ti,ab,kw OR ‘hygiene, dental’:ti,ab,kw OR ‘plaque index’:ti,ab,kw OR ‘gingival index’:ti,ab,kw OR ‘probing depth’:ti,ab,kw OR ‘bleeding on prob’:ti,ab,kw OR ‘bleeding on probing’:ti,ab,kw OR ‘marginal bone’:ti,ab,kw OR ‘patient hygiene performance index’:ti,ab,kw OR biofilm:ti,ab,kw #2 braille:ti,ab,kw #3 ‘visually impaired person’/mj OR ‘blindness’/mj OR ‘visually impaired’:ti,ab,kw OR blind*:ti,ab,kw OR ‘visually impaired’:ti,ab,kw Search #1 and #2 and #3
Lilacs via VHL (0)	((mh:(visually impaired persons)) OR (mh:(blindness)) OR (tw:(“visually impaired” OR blind* OR “Impaired Visually”))) AND ((tw:(braille))) AND ((mh:(dental caries)) OR (mh:(oral hygiene)) OR (mh:(oral health)) OR (tw:(“dental decay” OR “white spot” OR “white spots” OR Demineral* OR ECC OR DMF OR DMFT OR “decayed, Missing, and Filled Teeth” OR Deft OR DMFS OR ICDAS OR NIVAD OR carious OR carie* OR “oral hygiene” OR “oral health” OR “Hygiene, Oral OR Dental Hygiene” OR “Hygiene, Dental OR Plaque Index” OR “Gingival index” OR “probing depth” OR “bleeding on prob” OR “bleeding on probing” OR “marginal bone” OR “Patient Hygiene Performance index” OR biofilm))))
OpenGrey (0)	Braille AND (oral hygiene) Braille AND caries Braile AND biofilm

methodological quality assessment of the included studies independently.

Meta-analysis

Data from the studies were analyzed using RevMan software (Review Manager v. 5.3, The Cochrane Collaboration; Copenhagen, Denmark) to evaluate gingival and plaque index between the groups that used Braille, alone or in combination, and the groups that did not use Braille for oral health education. The mean, standard deviation, and number of participants assessed in each health education group (with and without Braille) were extracted and inserted into the software for calculation of the mean difference (MD) with a 95% confidence interval (CI). The analyses were performed according to the similarity between the health education methods. In cases in which the studies presented more than one intervention/ comparator group, the mean and standard deviation of the grouping was calculated through the random effect, with the aid of the Comprehensive Meta- analysis software.

The random effect model was applied, heterogeneity was tested using the I^2 index, and the prediction interval was calculated for analyses that included 3 or more studies.

Assessment of the certainty of EVIDENCE

The certainty of the evidence for each meta-analysis was determined using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach. According to the factors that decrease (risk of bias, inconsistency, external validity, imprecision, and publication bias) or increase (magnitude of effect, presence of spurious relationship/confounding factors, and dose response) the confidence in the results, the quality of the evidence can range from very low to high (9).

RESULTS

Search and selection of studies

Initially, 70 articles were identified. After removing the duplicates, 34 studies remained and, of these, 19 were selected for the full text reading. After careful reading, 10 articles were excluded for not meeting the eligibility criteria: 1 study did not present control without Braille, 8 studies presented before and after design, and 1 study did not perform randomization. Finally, 9 articles were included in the present review and 5 in the meta-analysis (Figure 1).

Data Extraction

The included studies were developed in India (2,4,6,7,10,13) and Indonesia (14), published between 2015 and 2019. Three studies included totally blind children (5,6,10), one study (13) included both totally and partially blind children, and five other studies (2,4,7,11,14) did not report the degree of visual impairment of the participants.

Braille was evaluated alone in 4 studies (4,6,7,13), associated with audio in 5 (2,6,10,11,14), associated with ATP in 2 (7,13), and with the tactile model in only 1 study (5). Braille was only evaluated in association with more than two techniques in three studies (6,10,11).

Oral Hygiene knowledge was assessed in 4 studies by applying questionnaires (2,6,13,14), plaque index was not assessed in 3 studies (4,11,14), gingival index was assessed in 4 studies (2,5,10,13) and in 2 the patient's hygiene performance was evaluated (4,11).

Table 2 and 3 show the characteristics and numerical results of the included studies, respectively.

Risk of bias

According to the RoB 2.0 tool, all studies were rated as "some concerns" in the domain related to the reporting of results, since they did not submit their designs. Additionally, six studies (4,10,11,12,14,15) were judged as "some concerns" in the domain related to bias during the randomization process as they did not describe how the method of randomization of included participants was performed ("Was the allocation sequence randomized?") as well as the blindness of the allocation sequence until enrollment and assignment to the interventions ("Was the allocation sequence blinded until participants were enrolled and assigned to the interventions?"). Seven studies (2,4,7,10,11,14,15) were rated as "some concerns," primarily for lack of information related to analyses to estimate the effect of assignment to interventions ("Was an appropriate analysis used to estimate the effect of assignment to the intervention?") and its impact ("Was there potential for a substantial impact, on outcome, of failing to analyze participants in the group to which they were randomized?").

Overall, all studies included in the present systematic review were rated as "some concerns." The risk of bias in the included studies is shown in Figures 2 and 3.

Meta-analysis and certainty of EVIDENCE

It can be observed that patients who received oral hygiene instructions with Braille associated with the tactile method, audio or ATP presented mean gingival index similar to the group of patients who received OHI without Braille ($p>0.05$). A significant difference was detected in the comparison Braille *versus* ATP, in which the group that received OHI using only Braille presented higher mean gingival index when compared to the group that received OHI through ATP (figure 4).

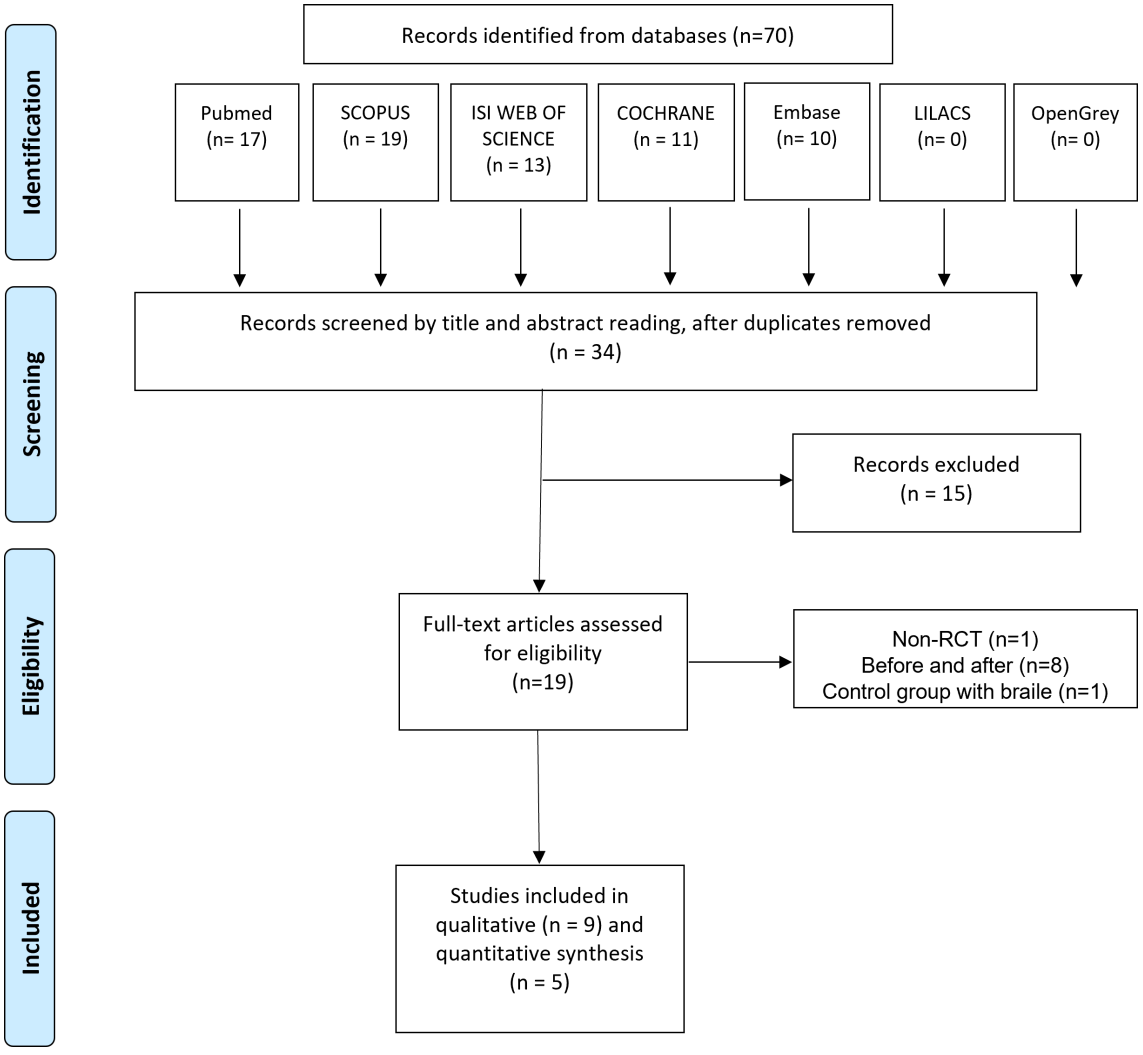

Figure 1. *Flowchart of study selection and inclusion.*

TABLE 2. DATA DESCRIPTION OF THE INCLUDED STUDIES.

Study			Population		Comparisons		Time of application of the educational method	Time of Evaluations	Key Figures or Outcomes Assessed	Losses in the groups
Author, year. Country.	Design	Exclusion Criteria	Age	Blindness level	Braille	Without Braille				
Alamsyah et al. 2017. Indonesia.	RCT	Wearing an orthodontic appliance and not presenting systemic abnormality.	> 5 Years old	NR	Braille (n=49).	Audio (n=44).	Once a day for 1 month.	1 week and 1 month after PE.	Knowledge about OH (12-question questionnaire) and OHIS.	0
Chowdary et al. 2016. India.	RCT	Children with other forms of mental or physical disabilities, medically compromised children, who use any chemical mode of plaque control, and under medication that can affect the condition of the gum tissues.	06-16 Years Old	Totally visually impaired since birth.	G2. Verbal + Braille (n=40). G3. Verbal + tactile (ATP) + Braille (n=40).	G1. Verbal + Tactile (ATP) (n=40).	NR	1, 3 and 6 months after EP.	Plaque index - (Silness and Loe) Gingival index - (Loe and Silness).	NR
Das et al. 2018. India.	RCT	Individuals with any other additional disabilities or syndromes, systemic diseases, uncooperative individuals, who are using any other oral hygiene supplements, with a recent history of dental treatment, systemic antibiotics or topical fluoride treatments 3 months prior to data collection, and individuals with dentures.	10-15 Years Old	NR	Braille + Audio resources (n=30).	ATP (n=30).	Periodically every three weeks.	30 and 90 days after EP.	Oral health knowledge and practice questionnaire, plaque and gingival index.	0
Deshpande et al. 2017. India.	RCT	Individuals with any other disability or syndrome and non-cooperative.	12-16 Years old	NR	G1. Braille (n=20). G3. Braille + ATP (n=20).	G2. ATP (n=20).	Reinforcement of the brushing technique was performed on the seventh day and after one month from the day the patients were first taught.	6 months post EP.	Plate index.	0

Ganapath et al. 2015. India.	RCT	Partially blind children, with underlying systemic disease and/or other disability, in orthodontic treatment, and non-cooperative.	08-14 Years old	Totally visually impaired child.	G2. Braille (n=40). G4. Braille + Audio + Tooth models (n = 40).	G1. Audio (n = 40). G3. Tooth models (n = 40). G5. No information (n = 40).	NR	8 months after EP.	Plaque index and oral health knowledge.	
Gautam et al. 2018. India.	RCT	Children with a recent dental treatment, history of systemic antibiotics or topical fluoride treatments, xylitol chewing gum, severe medical conditions.	05-18 Years old	NR	G1. Braille + Audio Resources (n = 20). G3. Braille + Audio resources + Tooth models (n = 20).	G2. Audio resources + Tooth models (n=20).	NR	1 and 3 months after EP.	PHP Index.	0
Gautam et al. 2020. India.	RCT	NR	09-17 Years old	NR	G1. Braille (n=60). G3. Braille + ATP (n=60).	G2. ATP (n=60).	The reinforcements were performed periodically every 15 days.	Initial consultation and after 3 months.	Plaque and gingival index.	0
Tiwari et al. 2019. India.	RCT	Medically compromised children, children with intellectual disabilities, children using any chemical mode of plaque control, and children on medications that can affect the condition of the gum tissues.	12-15 Years old	Partial and complete blindness (visual acuity ranging from 6/60 to 1/60).	G2. Braille (n=30). G3. Braille + ATP (n=30).	G1. Audio + Tactile (ATP) (n=30).	Periodically reinforced (unspecified).	21 days, 3, 6 and 9 months after EP.	Knowledge, plaque and gingival index.	0
Mahantesha et al. 2015. India.	RCT	Individuals with a recent history of dental treatment, systemic antibiotics or topical fluoride treatments 3 months prior to the initial appointment, habitual use of probiotics, xylitol chewing gum, serious medical conditions.	6-20 Years Old	NR	G1. Braille (n=25).	G2. Audio (n=25).	NR	7 days and 3 months after EP.	PHP index.	0

RCT Randomized clinical trial; NR Not reported; EP Educational program.

TABLE 3. DESCRIPTION OF THE NUMERICAL RESULTS AND CONCLUSION OF THE INCLUDED STUDIES.

Study	Results	Conclusion
Alamsyah et al. 2017. Indonesia.	*Oral Hygiene Knowledge* Database: Braille: 5.08±1.59 / Audio: 4.48±1.21. After 1 week: Braille: 10.57±1.59 / Audio: 10.52±1.81. After 1 month: Braille: 10.92±1.13 / Audio: 11.20±0.98. *OHIs* Database: Braille: 2.99±1.02 / Audio: 2.90±0.76 After 1 week: Braille: 1.77±0.71 / Audio:1.66±0.69 After 1 month: Braille: 1.56±0.63 / Audio: 1.44±0.72	The gain in knowledge and OHIs was similar in children who received OHI by audio and Braille.
Chowdary et al. 2016. India.	*Plaque Index* G1. Baseline: 0.91±0.29 / 1 month: 0.65±0.21 / 3 month: 0.46±0.16 / 6 month: 0.42±0.20 G2. Baseline: 1.00±0.20 / 1 month: 0.69±0.15 / 3 month: 0.60±0.10 / 6 month: 0.41±0.16 G3. Baseline: 1.09±0.19 / 1 month: 0.64±0.16 / 3 month: 0.40±0.14 / 6 month: 0.32±0.17 *Gingival Index* G1. Baseline: 0.52±0.32 / 1 month: 0.26±0.18 / 3 months: 0.13±0.11 / 6 months: 0.11±0.10 G2. Baseline: 0.74±0.25 / 1 month: 0.49±0.29 / 3 months: 0.19±0.08 / 6 months: 0.11±0.07 G3. Baseline: 0.65±0.17 / 1 month: 0.31±0.15 / 3 months: 0.13±0.10 / 6 months; 0.12±0.11	The combination of verbal instruction, Braille texts, and tactile mode of oral health education proved to be an effective tool for instilling good oral hygiene practices in visually impaired children.
Das et al. 2018. India.	*Plaque Index* Braille + Audio Database: 2.63 ± 2.02 / 30 days: 3.58 ± 1.3 / 90 days: 3.14 ± 0.88 ATP Database: 2.75 ± 1.76 / 30 days: 3.45 ± 1.9 / 90 days: 3.5 ± 1.18 *Gingival Index* Braille + Audio Database: 4.12 ± 1.66 / 30 days: 0.92 ± 2.52 / 90 days: 1.97 ± 1.48 ATP Database: 4.58 ± 1.63 / 30 days: 1.23 ± 2.43 / 90 days: 2.65 ± 1.64	ATP was considered equal to the control group (Braille and audio resources).
Deshpande et al. 2017. India.	G1. Database: 29.45 / 6 months: 42.98 G2: Database: 30.83 / 6 months: 29.90 G3. Database: 30.23 / 6 months: 18.73	Braille + ATP proved more effective than Braille and ATP alone.
Ganapath et al. 2015. India.	Plaque Index G1. Before (3.02 ± 0.90) / After (2.07 ± 0.63) G2. Before (2.73 ± 0.83) / After (2.35 ± 0.47) G3. Before (2.61 ± 0.82) / After (1.86 ± 0.51) G4. Before (2.63 ± 0.76) / After (1.80 ± 0.45) G5. Before (2.75 ± 0.51) / After (NR)	Multisensory approach that proved to be more effective than the unisensory mode.
Gautam et al. 2018. India.	G1. Base data: 0.75 (±0.44) / 1 month 0.55 (±0.51) / 3 months 0.3 (±0.47) G2. Base data: 0.65 (±0.49) / 1 month 0.55 (±0.51) / 3 months 0.35 (±0.49) G3. Base data: 0.65 (±0.49) / 1 month 0.50 (±0.51) / 3 months 0.15 (±0.37)	The combination of audio, Braille, and tactile models is an effective way to provide oral health education and improve the oral health status of visually impaired children.
Gautam et al. 2020. India.	*Plaque Index* G1. Baseline: 1.67± 0.51 / 3 months 1.16 ± 0.42 G2. Baseline: 1.85 ± 0.43 / 3 months 0.96 ± 0.31 G3. Baseline: 1.84 ± 0.39 / 3 months 0.80 ± 0.27 *Gingival Index* G1. Baseline: 1.7 ± 0.48 / 3 months 1.2 ± 0.45 G2. Baseline: 1.87 ± 0.38 / 3 months 1.00 ± 0.32 G3. Baseline: 1.85 ± 0.33 / 3 months 0.79±0.18	Visually impaired children can maintain an acceptable level of oral hygiene when taught using a combination of the Braille and ATP technique.

Tiwari et al. 2019. India.	*Plaque Index* G1. Base data: 1.68 ± 0.26 / 21 days 1.35 ± 0.17 / 3 months 1.15 ± 0.16 / 6 months 1.03 ± 0.13 / 9 months 0.93 ± 0.13 G2. Base data: 1.70 ± 0.29 / 21 days 1.62 ± 0.29 / 3 months 1.40 ± 0.24 / 6 months 1.25 ± 0.21 / 9 months 1.10 ± 0.19 G3. Base data: 1.74 ± 0.29 / 21 days 1.21 ± 0.22 / 3 months 1.01 ± 0.20 / 6 months 0.91 ± 0.18 / 9 months 0.79 ± 0.14 *Gingival Index* G1. Base data: 1.78 ± 0.25 / 21 days 1.43 ± 0.19 / 3 months 1.25 ± 0.15 / 6 months 1.12 ± 0.12 / 9 months 1.03 ± 0.12 G2. Base data: 1.81 ± 0.29 / 21 days 1.71 ± 0.30 / 3 months 1.50 ± 0.24 / 6 months 1.35 ± 0.20 / 9 months 1.20 ± 0.19 G3. Base data: 1.84 ± 0.29 / 21 days 1.31 ± 0.22 / 3 months 1.11 ± 0.19 / 6 months 1.01 ± 0.17 / 9 months 0.89 ± 0.13	The combination of ATP (audio, tactile, and performance technique) and Braille is an effective way to improve oral hygiene status in visually impaired children.
Mahantesha et al. 2015. India.	*PHP Index* G1. Baseline: 3.88±0.33 / 7 days: 3.42±0.36 / 3 months: 2.47±0.43 G2. Baseline: 3.90±0.38 / 7 days: 3.45±0.47 / 3 months: 2.86±0.42	Improved oral health status in the study population by decreasing the mean plaque score.

For specification of G1, G2, G3 and G4, see table 1.

TABLE 4: NUMERICAL RESULTS OF THE MATRIX ANALYSIS AND CERTAINTY OF EVIDENCE FOR GINGIVAL INDEX AND PLAQUE INDEX.

	No. of studies included	I^2	Difference from the mean	P value	Prediction interval	Certainty of evidence
Gingival Index						
Braille *versus* ATP	02	0%	0.23 [0.15, 0.31]	**<0.001**	NA	Very low ⊕◯◯◯
Braille + Audio *versus* ATP	02	70%	-0.20 [-0.89, 0.49]	0.57	NA	Low ⊕⊕◯◯
Braille + ATP *versus* ATP	03	90%	-0.11 [-0.25, 0.02]	0.10	NA	Very low ⊕◯◯◯
Plaque Index						
Braille + Audio *versus* ATP	02	40%	-0.08 [-0.36, 0.20]	0.56	NA	Low ⊕⊕◯◯
Braille *versus* Negative control*	04	61%	0.26 [0.13, 0.38]	**<0.001**	[-0.24 a 0.76]	Very low ⊕◯◯◯
Braille + ATP *versus* Control#	05	0%	-0.13 [-0.18, -0.09]	**<0.001**	[-0.19 a -0.07]	Moderate ⊕⊕⊕◯

DM. Difference from the mean; ATP. Audio tactile performance; NA. Not applicable; Control. Any other method without Braille.
**The control group (no Braille) in this analysis includes audio (1 study), tactile (1 study), and ATP (2 studies).*
 # The control group (no Braille) in this analysis includes audio (1 study), tactile (1 study), and ATP (3 studies).

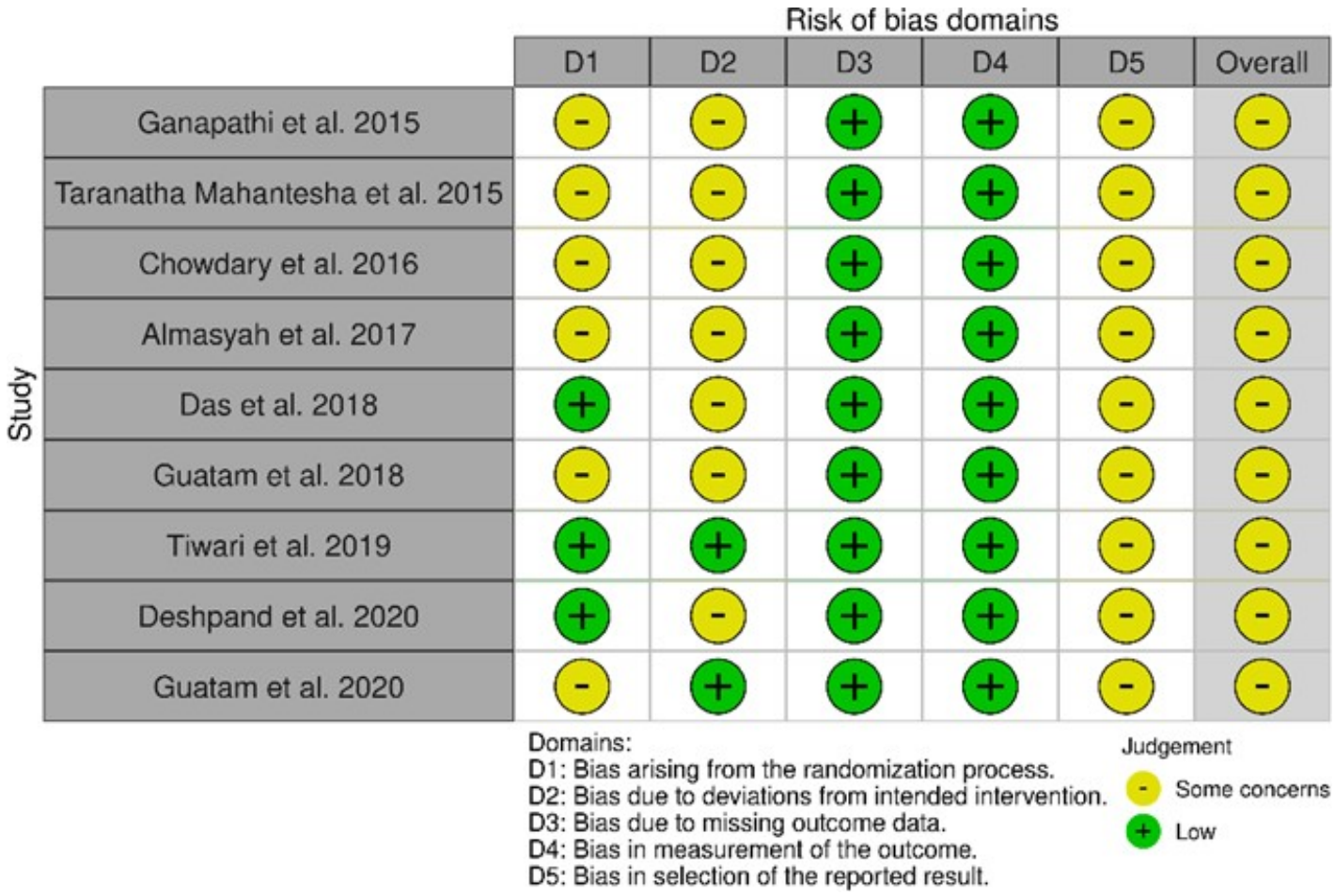

Figure 2: *Traffic light graph of the quality assessment of randomized trials (RoB.2).*

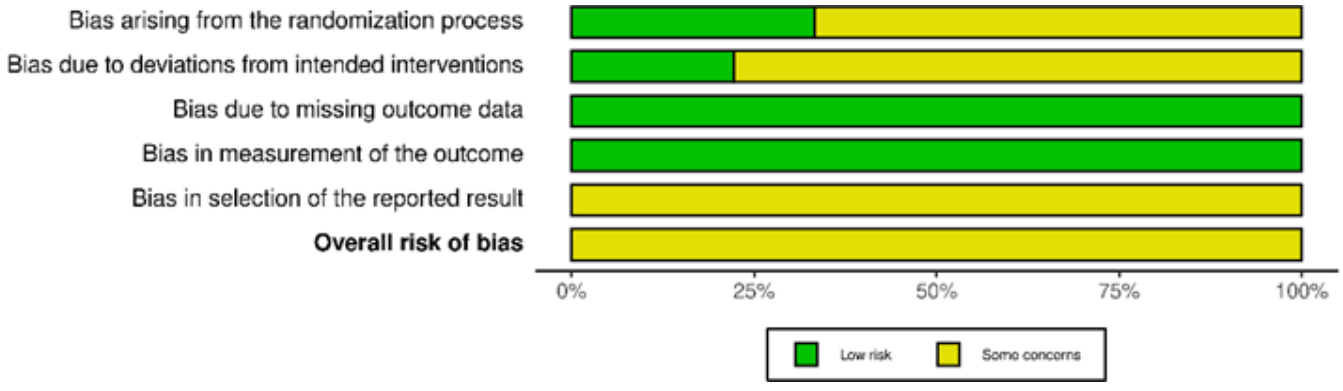

Figure 3. *Summary chart of the quality assessment of randomized trials (RoB.2).*

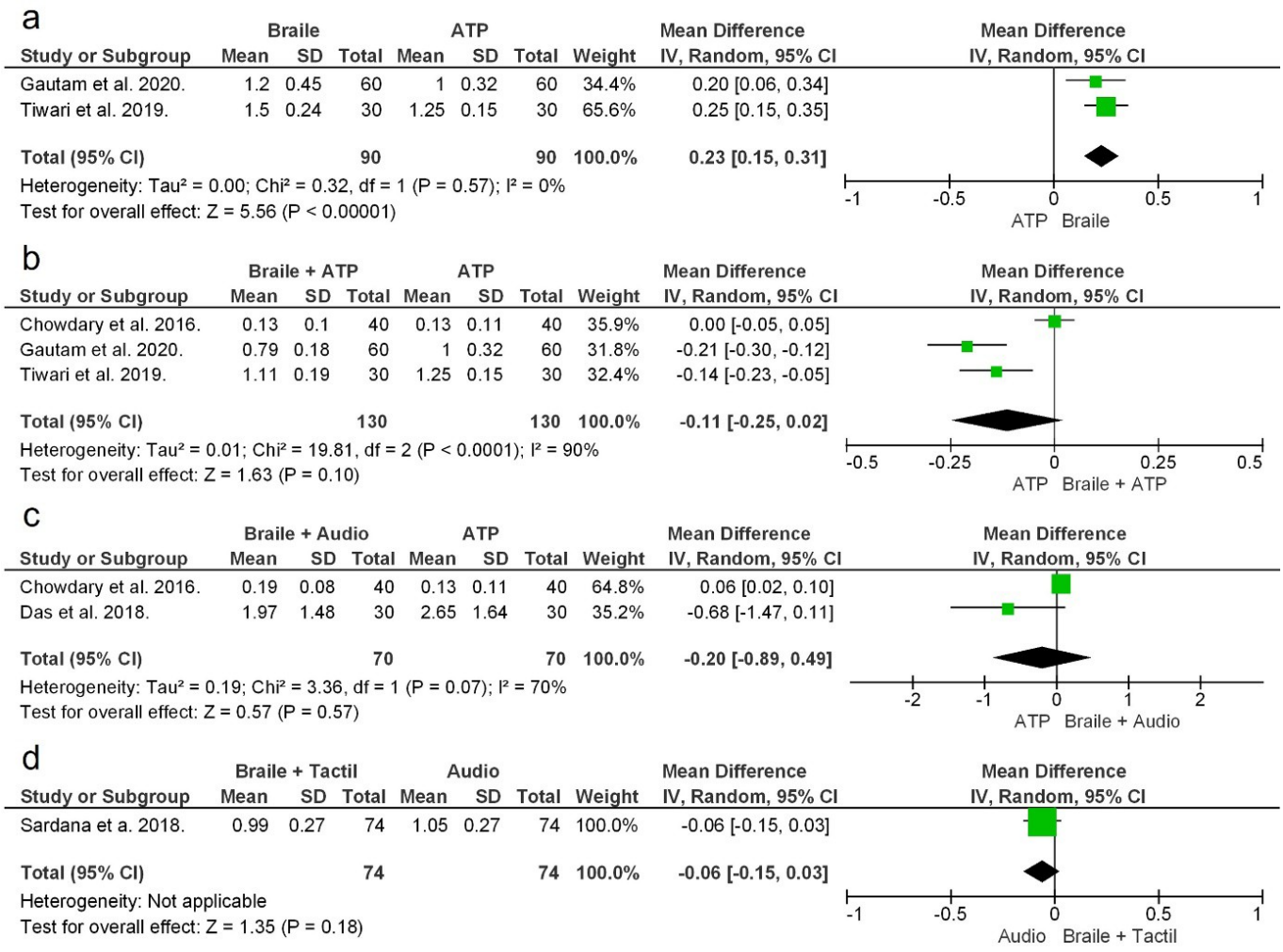

Figure 4. *Forest plot das análises para índice gengival: (a) Braile versus ATP, (b) Braile + ATP versus ATP, (c) Braile + Áudio versus ATP, (d) Braile + Tátil versus Áudio.*

Regarding plaque index, the group that received OHI with Braille only showed higher dental biofilm averages, compared to the groups that received different forms of OHI without Braille ($p<0.001$). Patients who received OHI using Braille associated with the tactile or audio method presented biofilm averages similar to the groups who received OHI without the Braille method ($p>0.05$). Only the group that received OHI through Braille associated with ATP showed lower biofilm averages compared to the groups that received different forms of OHI without Braille ($p<0.001$) (figure 5).

DISCUSSION

According to the data from the studies included in the present review, Braille, when used alone, is inferior to the other methods; when associated with audio or ATP, it is similar to ATP; and when implemented with ATP, it is superior to techniques without Braille.

Thus, it can be inferred that multisensorial methods including Braille are more efficient, while Braille used alone is less efficient, when both are compared to OHI methods without Braille. Visual impairment is characterized by a sensory deficiency (vision), leading to limitations for the people who have it and impairing their perception of the world (16). The multisensorial method allows a greater sensorial exploration and the development of different perceptive capabilities of the visually impaired individual, seeking to associate tactile and kinesthetic perceptions to the auditory stimuli.

ROB.2 is a tool used to consider the risk of bias in randomized clinical trial results, structured into five domains where bias can be introduced into the outcome (17). If performed successfully, randomization avoids the influence of known or unknown prognostic factors (factors that predict outcome) or confounding factors (factors related to the outcome) on the assignment of the intervention group (17). This means that, on average, the intervention groups have the same prognosis before the start of the intervention. Most studies did not provide details on how the process of randomization and allocation blindness was performed, as well as the possible impact of this process on group matching at the early stage of the clinical trial.

The clinical trial should be registered, as per CONSORT recommendations (18). Evaluation of this protocol minimizes intervention deviation and outcome reporting biases. Intervention drift relates to biases that arise when there are deviations from the intended interventions and may be related to administration of additional interventions not reported in the study protocol, failure to implement the protocol interventions as intended, or failure of study participants to adhere to their assigned interventions.

While reporting selection bias puts the outcome of a synthesis at risk because results are omitted based on their direction, magnitude, or statistical significance (17). Most studies did not provide the registration numbers of their protocols, so that biases related to intervention bias and reporting could be eliminated. The authors of the current review encourage that future studies be conducted based on the CONSORT statement to allow articles to provide complete, clear, and transparent information about their methodology and findings.

It is important to point out that all the studies included children and adolescents, and a small number of young adults, with the age of the participants varying from 5 to 20 years. The young age may have influenced the results, given that exposure to tactile stimuli is tiring for children, since they use another sensory channel (the hands). Studies highlight that tactile reading is more tiring than visual reading because it is slower, requires appropriate positioning of the arms and hands, requiring strength and manual dexterity to slide the fingers lightly over the text. Besides, temperature variations can cause a decrease in tactile sensitivity (19). Herein, further studies including adult and elderly populations should be carried out.

Another point worth noting is that almost all the studies included in the present review were conducted in India. This may be justified by the high prevalence of blindness in this country. Estimates suggest that there are 36 million blind people in the world (20), with India sharing almost a quarter of the entire global burden of blindness and visual impairment, with 8 million blind and 62 million visually impaired people (21).

The plaque index evaluated in some studies is the clinical analysis of the presence or absence of biofilm on the tooth surface and can assess whether brushing is being performed correctly. While the gingival index assesses inflammation and shows if the patient is performing oral hygiene and biofilm removal properly and routinely. The comparison between the method that included Braille and audio, or ATP showed similar results to the ATP method alone. While the Braille, when applied alone, showed inferior results to the ATP. It suggests that educational methods performed with Braille isolated may not provide adequate memorization of the content.

The knowledge related to oral hygiene was evaluated by questionnaires. In the study by Pagen *et al.* (14) the questionnaire consisted of 12 questions, while in the study by Das *et al*. (2) there were 17 questions. Both studies concluded that educational methods containing Braille are effective.

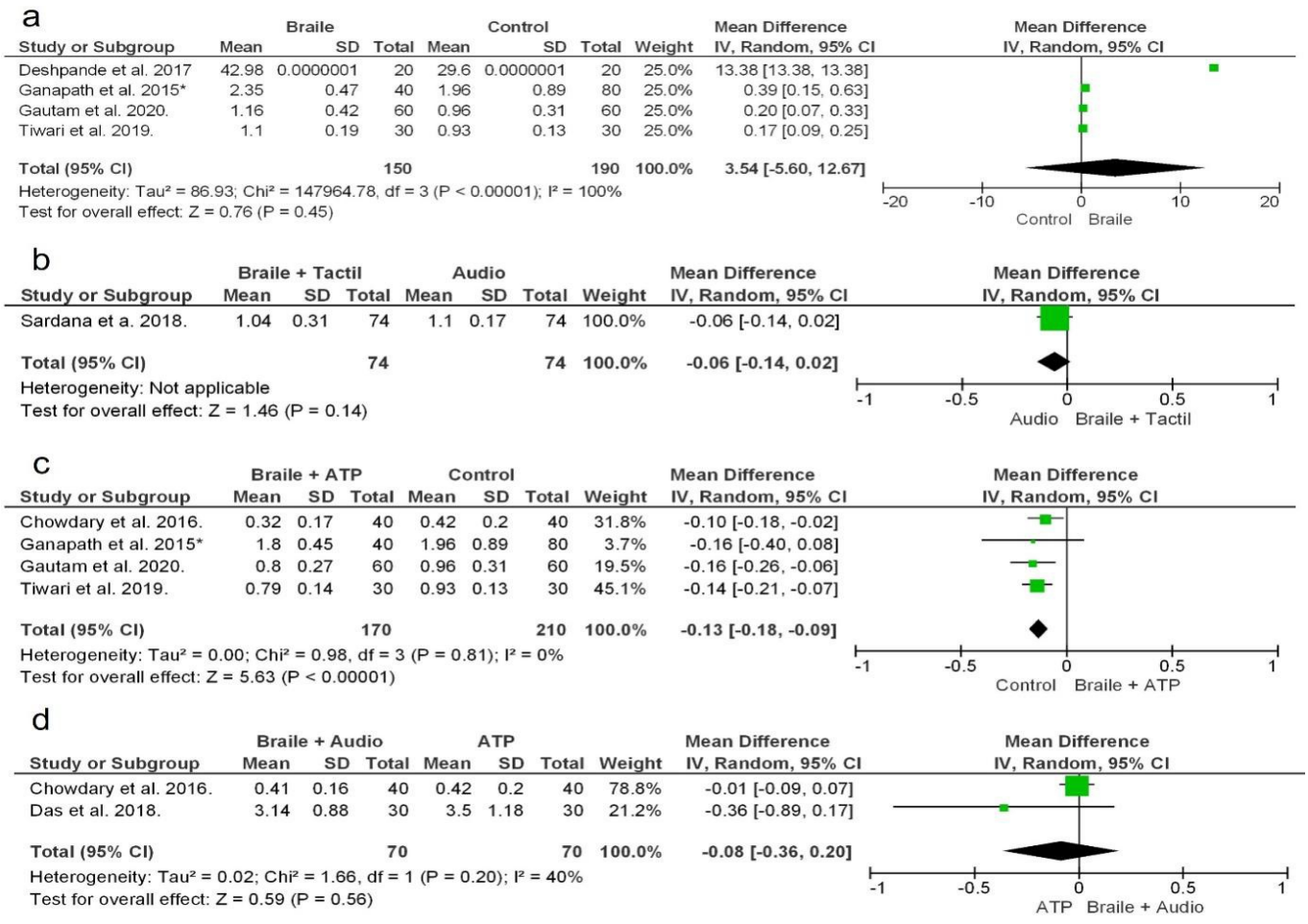

Figure 5. *Forest plot das análises para índice de placa: (a) Braile versus Controle, (b) Braile + Tátil versus Áudio, (c) Braile + ATP versus Controle, (d) Braile + Áudio versus ATP.*

Among the limitations of the present review we can cite the high heterogeneity of the studies included. The studies presented methodological differences in relation to the educational methods used, time of application and evaluation, as well as the indexes evaluated. These factors contributed to meta-analyses with a reduced number of included studies. Additionally, the presence of possible methodological biases contributes to the very low, low, and moderate certainty of the evidence. Future published studies may or may not agree with the results of the present meta-analysis.

The effort of dentists and teachers is extremely important, in order to include these habits in the routine of visually impaired youngsters. Dentists need to be qualified and aware of their importance in motivating oral hygiene instructions for this public, still so marginalized. Positive results are described when the instructions are given to the child with the help of others. The authors of the present review stimulate that projects on this theme, at universities and with the dentistry entities, must be carried out, since health is everyone's right and they will be working this way in favor of the inclusion of this population.

CONCLUSION

According to the data from the present review, Braille shows results equal to the negative control and inferior to the ATP when used alone as a method for oral health education. Only the Braille associated with the ATP showed better results among the multisensorial methods.

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ORIGINAL ARTICLE

INFLUENCE OF INSTRUMENTATION KINEMATICS ON ROOT CANAL SYSTEM PREPARATION: A SYSTEMATIC REVIEW OF STUDIES USING MICRO-COMPUTED TOMOGRAPHY

INFLUÊNCIA DA CINEMÁTICA DE INSTRUMENTAÇÃO NO PREPARO DO SISTEMA DE CANAIS RADICULARES: UMA REVISÃO SISTEMÁTICA DE ESTUDOS POR MICROTOMOGRAFIA COMPUTADORIZADA

Augusto Julio Munoz[1], Jefferson José de Carvalho Marion[2], Amanda Falcão[3], Daniel Rodrigo Herrera[4]

ABSTRACT

The aim of this study was to perform a systematic review of studies that evaluated by micro-computed tomography (micro-CT) the untouched areas of the root canal after preparation with rotary and reciprocating kinematics. Electronic search was carried out in LILACS, PubMed (MedLine), Science Direct, Cochrane, Scopus and Web of Science databases. An additional search for gray literature was performed on Google Scholar, OpenGrey, and ProQuest. The search covered studies in English, Portuguese and Spanish, with no restriction on publication time. Additionally, manual searches were carried out in the reference list of the included articles. *In vitro* studies that evaluated the percentage of untouched areas after root canal preparation, comparing rotary and reciprocating kinematics using micro-CT were selected. In total, 11 studies were selected for qualitative/quantitative analysis. One of them showed that the Reciproc (reciprocating) system has a lower percentage of untouched canal walls in lower incisors than the BioRace (rotary) system. Another study showed no significant differences between the Reciproc, WaveOne reciprocating systems and the BioRace system in mesial canals of mandibular molars. No differences were observed between ProTaper Next, ProTaper Universal (rotary) and WaveOne. A single study showed differences between kinematics, XP-Endo Shaper (rotary) showed a higher percentage of touched areas when compared to TRUShape (rotary) and WaveOne Gold. The evaluated studies showed that none of the instrumentation systems, regardless of kinematics, was able to completely touch the root canal walls.

Keywords: Endodontics, Root Canal Preparation, X-Ray Microtomography.

RESUMO

O objetivo deste estudo foi realizar uma revisão sistemática dos estudos que avaliaram por microtomografia computadorizada (micro-CT) as áreas não tocadas do canal radicular após o preparo com cinemática rotatória e reciprocante. Foram utilizadas estratégias eletrônicas de busca nas bases LILACS, PubMed (MedLine), Science Direct, Cochrane, Scopus e Web of Science. Uma busca adicional por literatura cinzenta foi realizada no Google Scholar, OpenGrey e ProQuest. A busca abrangeu estudos em inglês, português e espanhol, sem restrição ao tempo de publicação. Adicionalmente, realizou-se pesquisas manuais na lista de referências dos artigos incluídos. Foram selecionados os estudos *in vitro* que avaliaram por micro-CT a porcentagem de áreas não tocadas após o preparo do canal radicular, comparando as cinemáticas rotatória e reciprocante. No total, 11 estudos foram selecionados para análise qualitativa/quantitativa. Um deles mostrou que o sistema Reciproc (reciprocante) tem uma porcentagem menor de paredes não tocadas do canal em incisivos inferiores que o sistema BioRace (rotatório). Outro estudo não mostrou diferenças significativas entre os sistemas reciprocantes Reciproc, WaveOne e o sistema BioRace em canais mesiais de molares inferiores. Não foram observadas diferenças entre ProTaper Next, ProTaper Universal (rotatórios) e WaveOne. Um único estudo apresentou diferenças entre cinemáticas, XP-Endo Shaper (rotatório) mostrou maior porcentagem de áreas tocadas quando comparado com TRUShape (rotatório) e WaveOne Gold. Os estudos avaliados mostraram que nenhum dos sistemas de instrumentação, independente da cinemática, foi capaz de tocar completamente as paredes dos canais radiculares.

Palavras-chave: Endodontia, Preparo de Canal Radicular, Microtomografia por Raio-X

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INTRODUCTION

The chemical-mechanical preparation of the root canal is an important step in endodontic treatment. Its objective is the complete removal of the remaining pulp tissue, microorganisms, and infected dentin; as well as the modeling of the root canal system (RCS), through the mechanical action of endodontic instruments and the chemical action of auxiliary chemical substances, providing adequate conditions for filling and sealing (1).

Several nickel-titanium (NiTi) instrumentation systems are developed to optimize mechanical instrumentation with differences in design, alloy heat treatment and instrumentation kinematics (2- 4). Available systems, regardless of their kinematics, do not achieve complete RCS debridement, leaving large areas of untouched walls (5-7). Bacteria located in these areas have the potential to remain dormant and be responsible for persistent periapical inflammation (1,8).

Two-dimensional (2D) radiographic images from different directions and serial slice methods were commonly used to compare the modeling capabilities of different instrumentation systems. However, limitations in reproduction and the invasive nature of sample sections have been described as major disadvantages (9,10). Advances in diagnostic imaging procedures are at the forefront of dental research and find in micro-computed tomography (micro-CT) a non-invasive, high-resolution imaging technology capable of overcoming the limitations of 2D and slice analysis (11-14).

The technology provided by micro-CT makes it possible to reproduce and reconstruct the root canal system three-dimensionally (3D) (15), being widely used in endodontic research to assess the modeling capacity of the instruments (11). Knowledge of the properties and modeling capabilities of rotary and reciprocating instruments is essential to help professionals selecting the most appropriate instrument for each clinical situation.

Thus, the aim of this study was to perform a systematic review focused on studies that used micro-CT analysis in the assessment of untouched canal areas after preparation with continuous rotary and reciprocating kinematics. The null hypothesis to be tested is that there is no significant difference in the percentage of untouched areas after preparation with continuous rotary and reciprocating kinematics.

MATERIAL AND METHODS

Protocol and Registration

This systematic review was performed according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (16,17). The study is registered in the International prospective register of systematic reviews (PROSPERO) (CRD42022326086).

PICO

The research question was designed based on the PICO principles: Population (*in vitro* studies evaluating, by micro-CT, the percentage of untouched areas after root canal preparation); Intervention (root canal preparation); Comparison (instrumentation kinematics – rotary and reciprocating); Result (percentage of untouched areas). The research question was finally defined as follows: In micro- CT analysis, does the instrumentation kinematics influence the percentage of untouched areas after root canal preparation?

Inclusion Criteria

Inclusion criteria consisted of *in vitro* studies that evaluated, using micro-CT, the percentage of untouched areas after root canal preparation, comparing rotary and reciprocating kinematics. It covered studies in English, Portuguese, and Spanish, without restriction in terms of publication time.

Exclusion Criteria

The following exclusion criteria were applied: 1) Studies without micro-CT evaluation; 2) Studies that did not compare the two kinematics; 3) Animal studies; 4) Reviews, letters, conference summaries, personal opinions, case reports; and 5) Full text not available.

Information source and search strategy

Electronic search strategies were used in LILACS, PubMed (MedLine), Science Direct, Cochrane, Scopus and Web of Science databases. An additional search for gray literature was performed on Google Scholar, OpenGrey, and ProQuest. In addition, manual searches were performed on the reference list of included articles.

Selection of studies

The selection process was carried out in two phases. In phase one, two reviewers (A.J.M. and D.R.H.) independently selected titles and abstracts from all identified references. Studies that did not meet the eligibility criteria were excluded. In phase two, the same two reviewers applied the eligibility criteria to the full text of the studies. A third reviewer (J.J.M.) was consulted in the event of a disagreement not resolved by a consensus discussion.

After inclusion of studies, if the necessary data were not found, efforts were made to contact the authors to retrieve unpublished data.

Risk of bias in INDIVIDUAL studies

During data extraction and quality assessment, any disagreements between reviewers were resolved through discussion and, if necessary, by involving a third author. For each aspect of the quality assessment, the risk of bias was scored based on Cochrane criteria [The Cochrane Handbook for Systematic Reviews of Interventions version 5.1.0 (http://handbook.cochrane.org)] adapted to the nature of the studies *in vitro*. The judgment for each record was "yes", indicating a low risk of bias, "no" indicating high risk of bias, and "unclear", indicating lack of information or uncertainty about the potential for bias.

If one or more criteria were not met, the study was scored as "high risk of bias". When the study was judged "unclear" in its key domains, attempts were made to contact the authors and obtain more information to define "low" or "high" risk.

Studies with similar interventions and outcomes would be considered for quantitative synthesis through meta-analysis. However, due to substantial heterogeneity among the included studies, the meta-analysis was not performed.

RESULTS

Selection of studies

Ninety-six studies remained after removing duplicates. Of these, 85 were discarded after applying the exclusion criteria based on reading the title and abstract. In the end, 11 studies met the requirements — as shown in the flow diagram (Fig. 1) — and had their full texts analyzed. No additional studies were added after manually searching the references of these studies. It was not necessary to discuss with the third reviewer to resolve disagreements, as the two initial reviewers agreed on the included studies.

Data extraction

A data extraction worksheet was created with the following information: first author, year of publication, country of affiliation of the first author, sample size, tooth type, canal curvature, resolution used in micro-CT, instrumentation systems used and percentage of untouched area (Table 1).

QUALITATIVE assessment of included studies

The overall bias and biases obtained due to the randomization process, selection of reported outcome, standardization of root anatomy, and operator variability are shown in Figure 2. An frustating attempt was made to contact the corresponding author of Yuan and Yang, 2018 (18) and clarify operator variability. The study was considered "unclear" in the general assessment (Fig. 2).

EVALUATED properties and results

The percentage of untouched areas during instrumentation was evaluated in this systematic review and is presented in Table 1. It was not possible to establish the influence of heat treatment on the modeling capacity of the different systems used in the evaluated studies.

DISCUSSION

Root canal instrumentation aims to eliminate compromised pulp tissue, microbial irritants and create ideal room for efficient irrigation, intracanal medication application and subsequent filling (8). Unprepared canal areas can compromise the disinfection of the root canal system and allow the maintenance of the infectious process, leading to endodontic failure (1,8).

The initial objective of this review included quantitative synthesis in the data to compare the effectiveness of the two kinematics in the modeling ability of root canals, but this was not possible due to the significant heterogeneity among the studies, involving the type of tooth examined, canal curvature, instrument design, and final instrumentation size, for example.

Through the qualitative evaluation of the included studies, it was possible to accept the proposed null hypothesis that there is no significant difference in the percentage of untouched areas after preparation with continuous rotary and reciprocating kinematics.

In the qualitative evaluation of the process of standardization of the initial root anatomy, the possibility of previous pairing by micro-CT of the specimens in the studies was considered relevantly positive (19-21). Micro-CT provides detailed information on roots and canals before instrumentation, proving to be effective in studying modeling after root preparation (20-23). Thus, only studies that used micro-CT were included in this systematic review.

Root canal instrumentation can result in large areas of untouched walls, regardless of the kinematics used during instrumentation (21,22). One study showed that the Reciproc (reciprocating) system has a lower percentage of untouched canal walls in mandibular incisors when compared to the BioRace (rotary) system, which could be explained by the taper and design of the instrument (21). Another study showed no significant differences between the Reciproc and WaveOne reciprocating systems and the BioRace system in mesial root canals of mandibular molars (24). Likewise, Zhao *et al.* did not observe any difference between ProTaper Next, ProTaper Universal (rotary) and WaveOne (25).

Paque et al. (2011) did not find differences when the ProTaper system was used in rotary or reciprocating

TABLE 1. CHARACTERISTICS OF THE STUDIES INCLUDED IN THE SYSTEMATIC REVIEW

Number	Author / Country	Tooth	Sample number	Curvature (grade)	Micro-CT Resolution (µm)	Groups	Untouched area (%)
1	Poly et al. (2021)/Brazil	Distal root of lower molars	30 (10 per group)	10 to 20	21.00	WaveOne Gold, TRUShape, XP-Endo Shaper	11.50 / 12.40 / 5.30
2	Da Silva et al. (2021)/Brazil	Lower premolars	33 (11 per group)	Not Available	22.00	TRUShape, Reciproc Blue R40, ProTaper Universal	39.80 / 45.40 / 47.90
3	Medeiros et al. (2021)/Brazil	Lower canines	30 (15 per group)	10 to 20	12.10	WaveOne Gold, Mtwo	7.96 / 10.18
4	Zuolo et al. (2018)/Brazil	Lower incisives	40 (10 per group)	Straight (<5)	14.25	BioRaCe, Reciproc, Self Adjusting File, TRUShape	32.38 / 18.95 / 16.08/ 19.20
5	Yuan & Yang (2018)/China	Mesial root of lower molars	20 (10 per group)	20 to 35	36.00	WaveOne, ProTaper Next	34.32 / 29.21
6	Espir et al. (2018)/Brazil	Lower incisives	54 (18 per group)	Not Available	17.42	Reciproc, Unicone, Mtwo	17.30 / 30.00 / 23.15
7	Guimaraes et al. (2017)/Brazil	Lower premolars	26 (13 per group)	Severe curvatures were excluded	19.9	TRUShape, Reciproc	24.00 / 30.00
8	De-Deus et al. (2015)/Brazil	Mesial root of lower molars	30 (10 per group)	10 to 20	14.16	Reciproc, WaveOne, BioRaCe	36-42 / 34-48 /42-47 (.25-.40)
9	Busquim et al. (2015)/Brazil	Distal root of lower molars	30 (15 per group)	<20	11.88	Reciproc R40, BioRaCe	15.12 / 9.73
10	Zhao et al. (2014)/China	Lower molars	36 (12 per group)	25-35 mesiovestibular canals / 15-25 mesiolingual canals / 5-20 distal canals	30.00	ProTaper Next, ProTaper Universal, WaveOne	41.50-36.90-55.30 / 41.40-38.40-56.30 / 39.60-35.30-52.10 (MV-ML-D)
11	Paqué et al. (2011)/Swissland	Mesial root of first lower molars	50 (25 per group)	20 to 40	20.00	ProTaper Universal rotary / A reciprocating PTU file	18.70 / 16.20

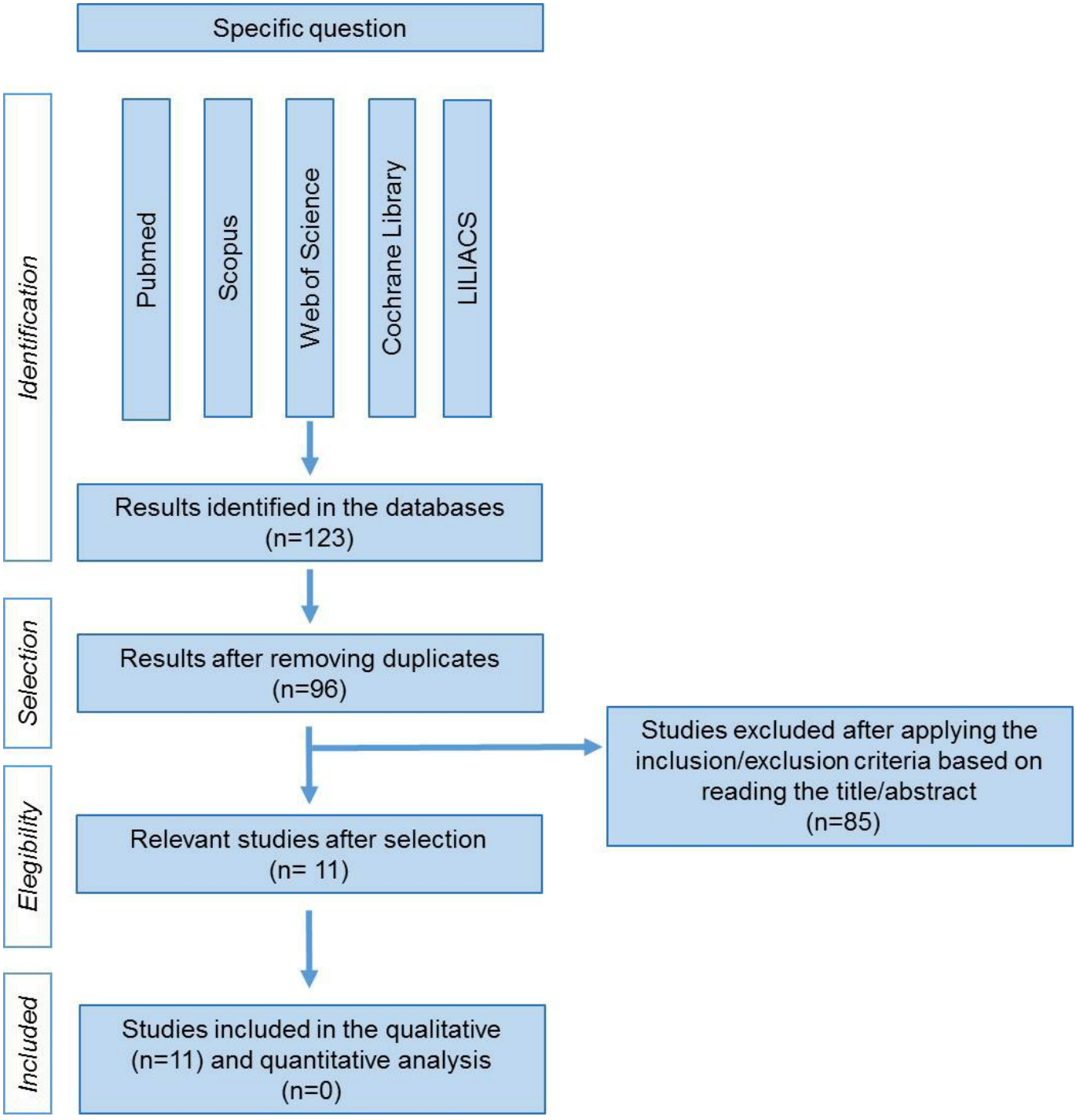

Figure 1. *Flowchart of the study selection.*

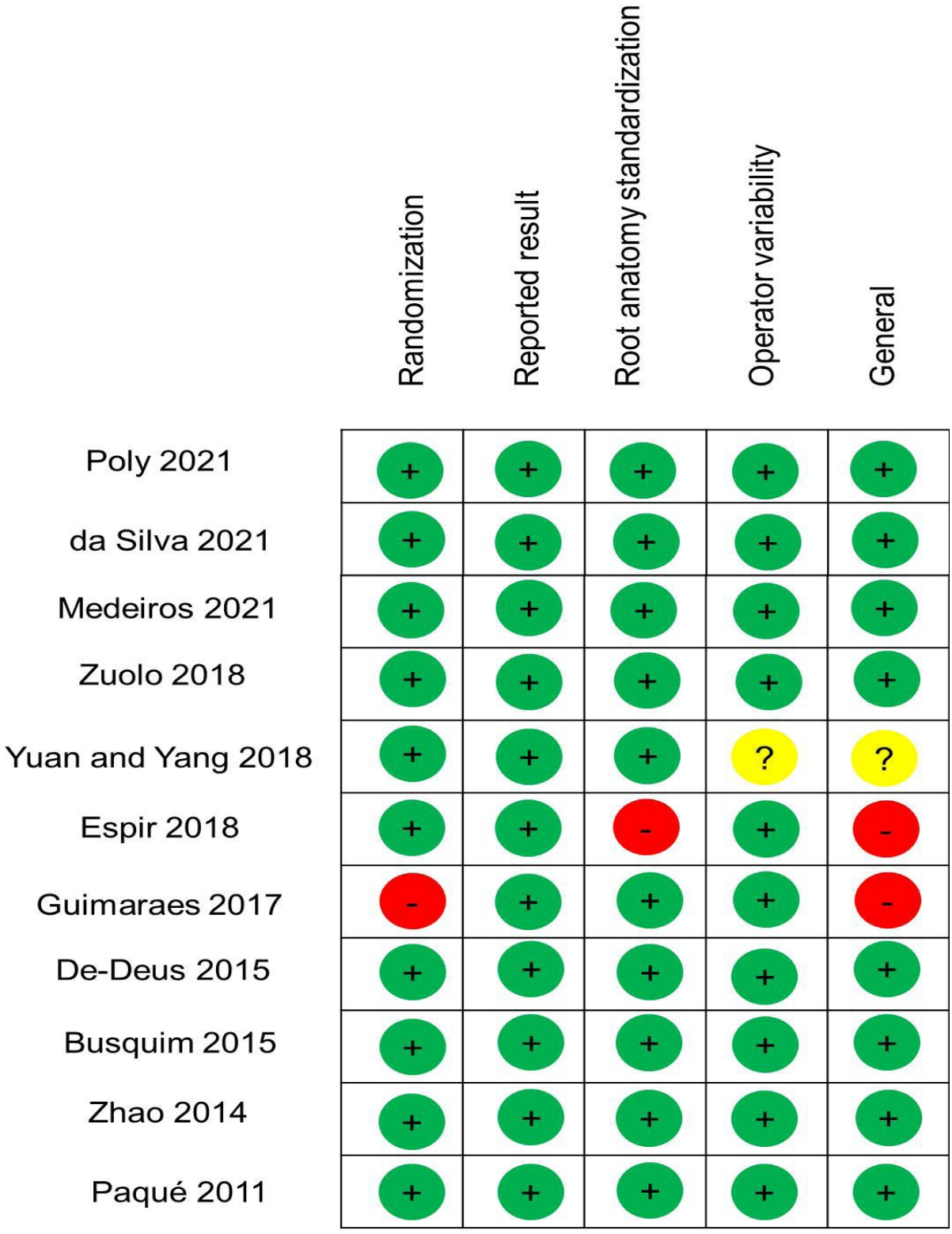

Figure 2. Analysis of risk of bias in included studies.

kinematics (26). Another study compared the Unicone reciprocating system with Reciproc R40 and MTwo (rotary) files; the results showed a greater amount of untouched areas in the Unicone system (22).

The TRUshape (rotary) system has fewer untouched areas (24%) in lower premolars compared to the Reciproc instrument (30%), justified by Guimarães *et al.* (2017) for the modeling created by the "S"-shaped rotary instrument that would facilitate instrumentation in flattened canals (19). On the other hand, the TRUShape system showed no differences with the WaveOne Gold system (reciprocal), also in flat canals. However, they were less effective in shaping the canal when compared with the XP-Endo Shaper (rotary) system (27).

Da Silva et al. (2021) also tested the TRUShape system, comparing it with the Reciproc Blue (reciprocating) system and the ProTaper Universal system, without observing significant differences in modeling capability (28). The authors justify the similar performance of the Reciproc Blue system in the fact that these instruments undergo a blue heat treatment in the manufacturing process, which increases their flexibility when compared to the Reciproc M-wire instrument, enhancing their ability to better follow the root canal anatomy, reaching a higher percentage of instrumented area (28).

Medeiros et al. (2021) compared the MTwo system with the WaveOne Gold system without observing significant differences in canal preparation. Nevertheless, when the final 5mm was evaluated, the WaveOne Gold system showed lower apical transport (28). The authors explain this result also by the heat treatment of the reciprocating system, which gives memory control to the instrument (29).

It is important to standardize the diameter and taper of the final instrument when comparing the shaping ability of different instruments (30). The data obtained showed different instrumentation protocols, regardless of kinematics. The differences between the untouched areas of the root canal system after instrumentation in rotary or reciprocating kinematics is still controversial, requiring further studies with greater control of the variables, reducing the heterogeneity of the various parameters in question (thermal treatment of NiTi alloy, cross-section of the instrument, diameter, taper, etc.), allowing a quantitative synthesis of the data.

CONCLUSION

The evaluated studies that used micro-CT showed that none of the instrumentation systems, regardless of kinematics, was able to completely touch the root canal walls.

The authors declare no conflicts of interest.

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CASE REPORT

MAXILLOFACIAL PROSTHESES IN THE AESTHETIC-FUNCTIONAL REHABILITATION OF CANCER PATIENTS

PRÓTESES BUCOMAXILOFACIAIS NA REABILITAÇÃO ESTÉTICO-FUNCIONAL DE PACIENTES ONCOLÓGICOS

Lísia Daltro Borges Alves[1], Ana Carolina dos Santos Menezes[2], Camila Santos Boasquevisque[3], Luciana Ferreira Stahel-Lage[4]

ABSTRACT

Introduction: Maxillofacial prostheses are a therapeutic option for the repair of affected structures in the facial and/or intraoral region of cancer patients undergoing surgery. **Objective:** To report the use of oral and maxillofacial prostheses in the aesthetic and functional rehabilitation of cancer patients. **Case reports:** The first two cases illustrate extraoral rehabilitations using silicone adhesive prostheses, both in female patients. The first one is an 83-year-old patient, diagnosed with basal cell carcinoma in the right nasal wing, submitted to surgical resection and rehabilitated with nasal prosthesis 7 months ago. The second case is a 51-year-old patient diagnosed with multiple sclerodermiform basal cell carcinomas, treated with surgery and rehabilitated with a facial prosthesis. The third case addresses the rehabilitation of a 58-year-old female patient, diagnosed with squamous cell carcinoma on the hard palate, treated with surgery and radiotherapy, rehabilitated with a palatal obturator prosthesis made of polymethylmethacrylate. **Conclusion:** The presented cases show oral maxillofacial prostheses as essential tools for reestablishing aesthetics and function in cancer patients, as well as their contribution to psychological issues, to the process of reinsertion into social life, and to improving the quality of life of these individuals. Furthermore, they confirm the importance of inserting the dentist in the multidisciplinary oncology team, with an emphasis on postoperative rehabilitation through maxillofacial prostheses.

Keywords: Maxillofacial Prosthesis; Oncology; Patient Care Team; Surgical Oncology; Dental Care for the Chronically Ill

RESUMO

Introdução: As próteses bucomaxilofaciais são uma opção terapêutica para o reparo de estruturas afetadas na região facial e/ou intraoral do paciente oncológico submetido à cirurgia. **Objetivo:** Relatar a utilização de próteses bucomaxilofaciais na reabilitação estético-funcional de pacientes oncológicos. **Relato dos casos:** Os dois primeiros casos ilustram reabilitações extraorais por próteses adesivas de silicone, ambos em pacientes do sexo feminino. O primeiro trata-se de uma paciente de 83 anos, com diagnóstico de carcinoma basocelular em asa nasal direita, submetida a ressecção cirúrgica e reabilitada por prótese nasal há 7 meses. O segundo, de uma paciente de 51 anos, diagnosticada com múltiplos carcinomas basocelulares esclerodermiformes, tratada com cirurgia e reabilitada há 8 meses com prótese facial. O terceiro caso aborda a reabilitação de uma paciente do sexo feminino, 58 anos, diagnosticada com carcinoma de células escamosas em palato duro, tratada com cirurgia e radioterapia, reabilitada há 1 ano e 6 meses com prótese obturadora de palato feita de polimetilmetacrilato. **Conclusão:** Os casos apresentados evidenciam as próteses bucomaxilofaciais como ferramentas essenciais no reestabelecimento da estética e função dos pacientes oncológicos, bem como a sua contribuição nas questões psicológicas, no processo de reinserção no convívio social e na melhora da qualidade de vida destes indivíduos. Além disso, ratificam a importância da inserção do cirurgião-dentista na equipe multiprofissional em oncologia, com ênfase na reabilitação pós-operatória através das próteses bucomaxilofaciais.

Palavras-chave: Prótese Maxilofacial; Oncologia; Equipe de Assistência ao Paciente; Oncologia Cirúrgica; Assistência Odontológica para Doentes Crônicos

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INTRODUCTION

Malignant neoplasms involving the head and neck region are a heterogeneous group (1,2) and can encompass an extensive variety of anatomical sites, such as skin, oral cavity, nasopharynx, hypopharynx, larynx, paranasal sinuses, and salivary glands (1-5). According to data released by GLOBOCAN, 19.3 million new cases of cancer were estimated in 2020; for 2040, the projection is 28.4 million new cases (6). For Brazil, it is estimated that 625,000 new cases will occur each year in the triennium 2020-2022 (7).

The treatment for these neoplasms can involve surgery, radiotherapy or chemotherapy, isolated or combined, according to the type, location and staging of the tumor (1,3,5). Surgical resection is the standard treatment when considering oral cavity tumors, and it can be associated with adjuvant chemotherapy and/or radiotherapy (1). In other sites, surgery is usually reserved for resectable primary tumors that have surgical access and allow free and wide margins (1,3,5). Despite its relevance, surgery often results in mutilations with considerable aesthetic and functional implications (8).

In this context, maxillofacial prostheses (MFP) are made to repair the affected structures in the facial and/or intraoral region of the patient. Thus, they contribute to the reestablishment of aesthetics, mimicking the removed structures and, in some cases, to the rehabilitation of essential functions such as speech, chewing and swallowing, also protecting the exposed tissues (9,10). The type and material of the MFP vary according to the site of the tumor, and may be of the palatal, nasal, facial, ocular, orbital, auricular or pharyngeal type (9,10) being made of glass, acrylic resin (polymethacrylate) and/or silicone (11). Therefore, MFP play a key role in the nutrition, systemic condition and quality of life of these individuals (12). Thus, the aim of this study was to report the use of oral and maxillofacial prostheses in the aesthetic-functional rehabilitation of cancer patients, treated at the Section of Stomatology-Dentistry and Prosthesis of the Hospital do Câncer I, Instituto Nacional de Câncer José Alencar Gomes de Almeida, Brazil.

CASE REPORTS

This is a descriptive, retrospective study of case series in which MFP (nasal, facial and obturator) were used for the esthetic-functional rehabilitation of oncologic patients, treated at the Section of Stomatology-Dentistry and Prosthesis of the Hospital do Câncer I, Instituto Nacional de Câncer José Alencar Gomes de Almeida, Brazil. This study was approved by the Ethics Committee (CAAE: 48142721.1.0000.5274, opinion no. 4.938.705), and the patients read and signed the informed consent form.

Case 1

An 83-year-old female patient diagnosed with basal cell carcinoma in the right nasal wing (T1N0M0), who underwent surgical resection (exeresis of the left malar region and the tip of the nose). One year after surgery an acrylic nasal prosthesis was made; however, the patient did not adapt to it, interrupting the use. For this reason, an adhesive silicone prosthesis was made, which was well accepted by the patient, presenting good adaptation of the margins and good aesthetic results. After 1 year, it was necessary to replace the prosthesis due to deterioration of the margins and fungal colonization. Figure 1 shows the current nasal prosthesis, which is the second adhesive silicone prosthesis, with 7 months of use, also showing good aesthetic results and good adaptation.

Case 2

Female patient, 51 years old, diagnosed with multiple sclerodermiform basal cell carcinomas, treated with surgery (extended exenteration of left orbit). After 6 years, she underwent plastic reconstruction of the surgical wound. She was rehabilitated with a facial prosthesis on the left side (orbital, nose wing and malar region), adhesive silicone, which has been in use for 8 months, with good adaptation, acceptance and aesthetics, using it mainly for social interaction (Figure 2).

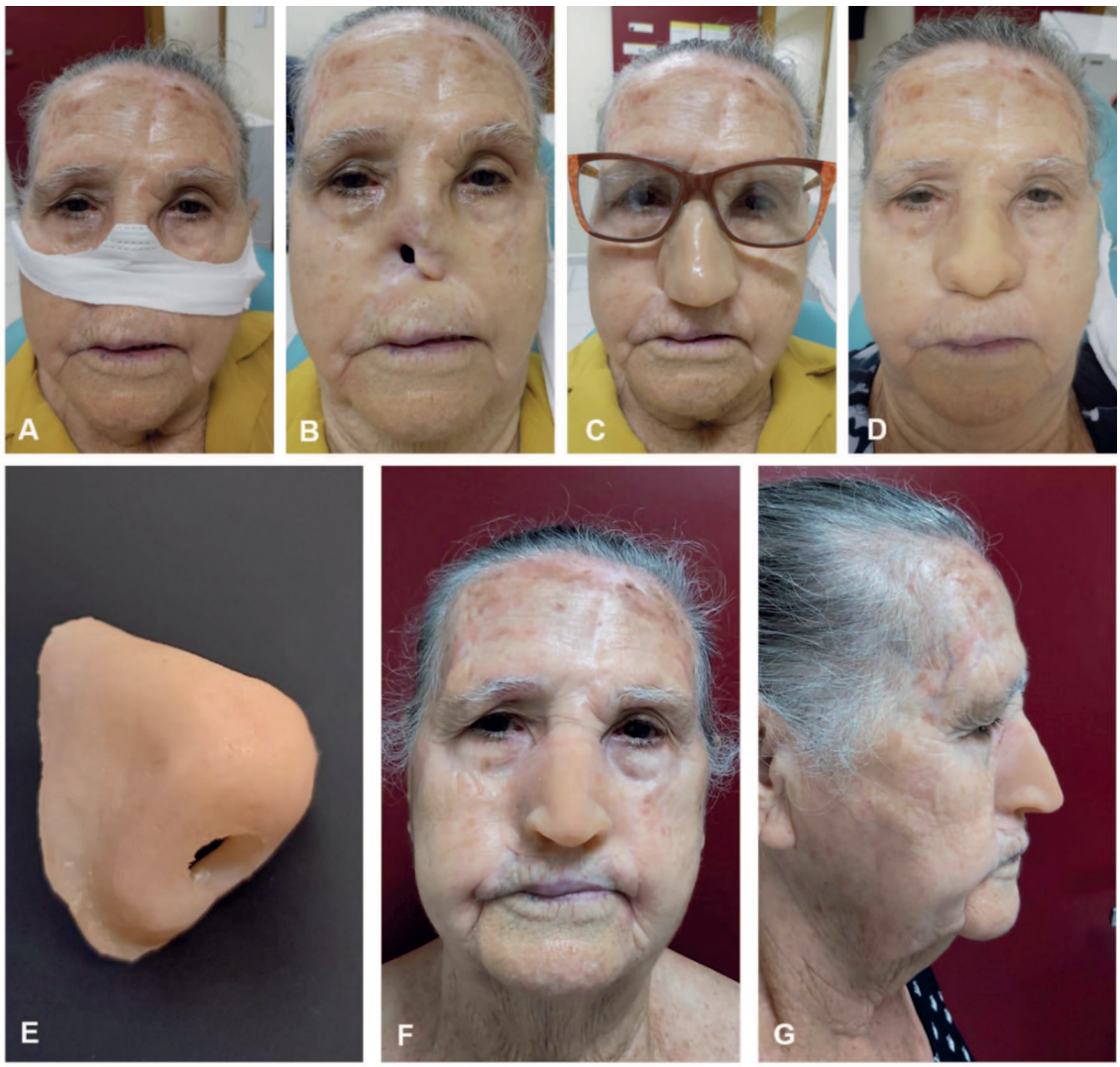

Figure 1: *Case 1, rehabilitation with nasal prosthesis.* **A**- *Front facial photograph without prosthesis, with wound dressing;* **B**- *Frontal photograph of face without the prosthesis;* **C**- *Frontal photograph of the face with initial acrylic prosthesis supported on glasses;* **D**- *Frontal photograph of face with the first silicone adhesive prosthesis;* **E**- *Photograph of the first silicone adhesive prosthesis;* **F**- *Frontal photograph of face with the second silicone adhesive prosthesis;* **G**- *Right profile photograph of face with second silicone adhesive prosthesis.*

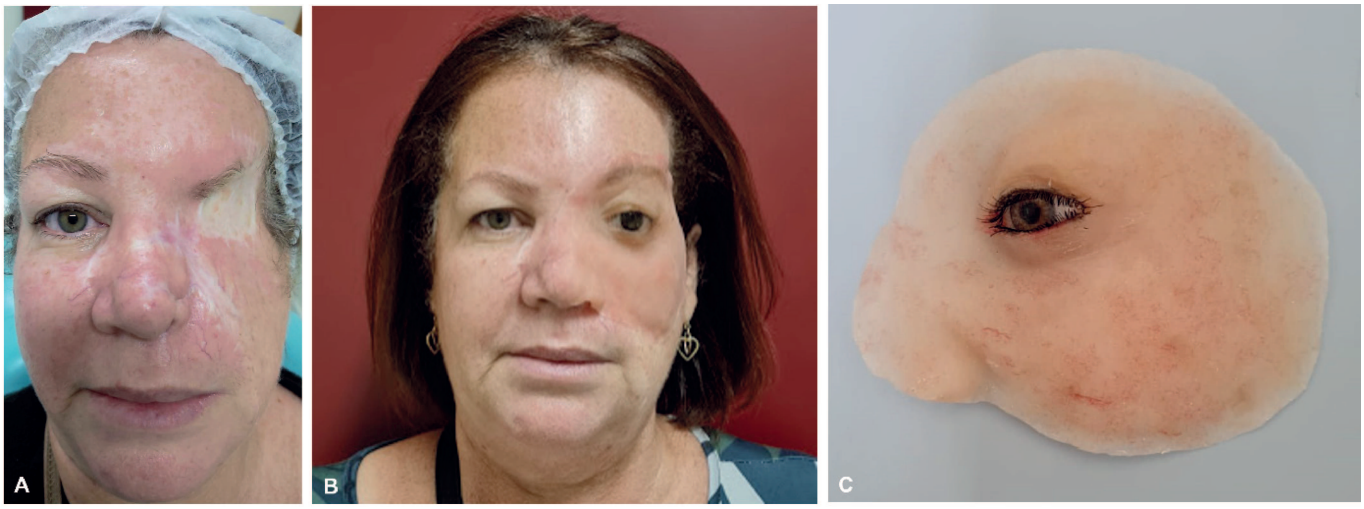

Figure 2: *Case 2, rehabilitation with facial prosthesis.* **A**- *Front facial photograph without the prosthesis;* **B**- *Front facial photograph with the prosthesis;* **C**- *Photograph of the silicone adhesive prosthesis.*

Case 3

A 58-year-old female patient was diagnosed with squamous cell carcinoma of the hard palate (T2N0M0). The treatment used consisted of surgery (bilateral infrastructure maxillarectomy) and adjuvant radiotherapy (66 Gy in 33 fractions). During the surgical procedure a surgical plate was installed and used for 4 months. After completion of radiotherapy, because the patient was edentulous, a removable upper obturator and lower conventional prosthesis were fitted. The patient had regular follow-up to control the prostheses, and currently, after 1 year and 6 months, she has well-fitting prostheses, with good retention, no complaints of pain, good chewing performance, good aesthetics and phonation (Figure 3)

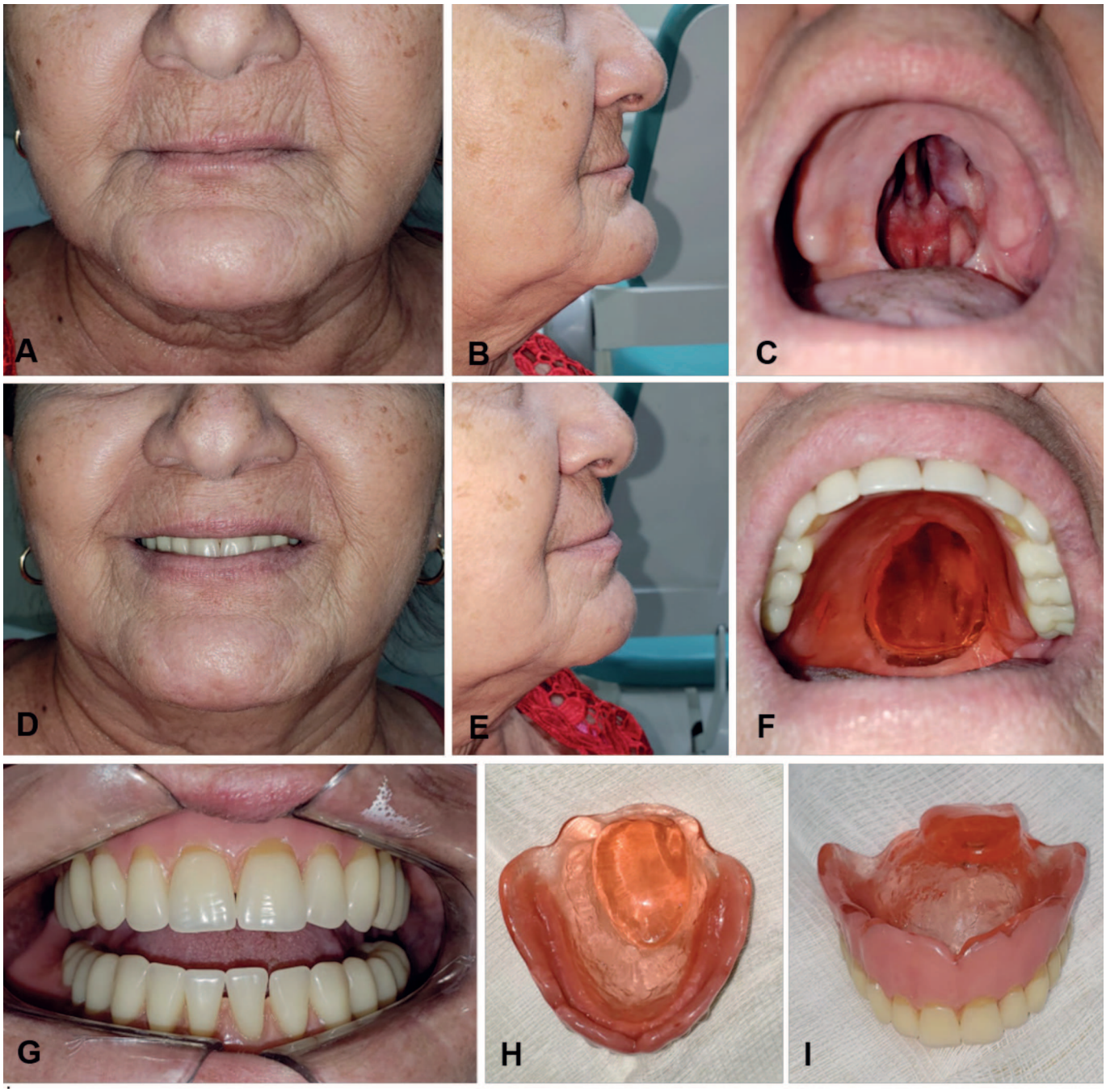

Figure 3: *Case 3, rehabilitation with removable total prosthesis, obturator for the upper jaw and conventional for the lower.* **A**- *Frontal extraoral photograph without prosthesis;* **B-** *Right profile extraoral photograph without prosthesis;* **C**- *Intraoral photograph of the palate, showing bucosinusal communication;* **D**- *Frontal extraoral photograph with prosthesis;* **E**: *Right profile photograph with prosthesis;* **F**: *Intraoral photograph of the palate with upper obturator prosthesis;* **G**: *Frontal intraoral photograph with removable total prosthesis;* **H**: *Upper view of the obturator prosthesis;* **I**: *Frontal view of the obturator prosthesis.*

DESCRIPTION OF TECHNIQUES

Nasal prosthesis

1. Patient image registration, with Frontal and profile photographs;
2. Modification and try-in of the prefabricated metal perforated tray (Tecnodent) (Figure 4.A);
3. Molding the area that will be reconstructed by the prosthesis and of adjacent structures that will serve as aesthetic reference (as for example the eyes and eyebrows) with alginate type II (Avagel, Dentsply Sirona) (Figure 4.B);
4. Disinfection of the mold with sodium hypochlorite and version in plaster type 4 (Dent-mix, Asfer) for making the model of the patient's face;
5. Markings the lines and reference points on the model for waxing the prosthesis: midline, labial commissure, bipupillary line, among others, according to the type of facial prosthesis;
6. Wax up of the amputated area with red wax 7 (Clássico), using the photographs as reference;
7. Wax up trial and adjustment on the patient's face (Figure 4.C and 4.D);
8. Choice of material for making the prosthesis: acrylic resin or silicone;

Acrylic resin (Thermopolymerizable acrylic resin no. 1, Clássico):

9. Choice of the color for intrinsic pigmentation through the personalized colorimetric scale (Figure 4.E). Intrinsic pigmentation must be carried out with Policôr dye or Lentaflex skin color base (Clássico);
10. Inclusion of the model and the wax up in a muffle with common plaster, removal of the wax and acrylization of the prosthesis (Figure 4.H);
11. Finishing by removing excesses with burs and sandpaper, followed by polishing with fiber sponge and detergent;
12. Try-in of the prosthesis on the patient's face and adjustments, if necessary;
13. Fixation with self-curing acrylic resin (Clássico) of the prosthesis in the patient's glasses and delivery of the prosthesis.

Silicone (silicone elastomer Dragon Skin 10, Polisil):

9. Choice of color for intrinsic pigmentation through the custom colorimetric scale (Figure 4.F and 4.G). The intrinsic pigmentation should be done with make-up base and Siq floc chamois powder (Siquiplás) red and gold until reaching the desired color;
10. Inclusion of the model and the wax-up in a muffle with common plaster, removal of the wax and vulcanization of the prosthesis (Figure 4.H);
11. Try-in of the prosthesis on the patient's face with adjustments if necessary;
12. Extrinsic pigmentation with make-up, finished by spraying a mixture (1:1) of transparent acetic silicone (Tekbond) with self-curing acrylic liquid (Clássico);
13. Application of the glue for Ultra Hold hair prosthesis (Walker Tape) on the internal part of the prosthesis, positioning on the patient's face and delivery of the prosthesis.

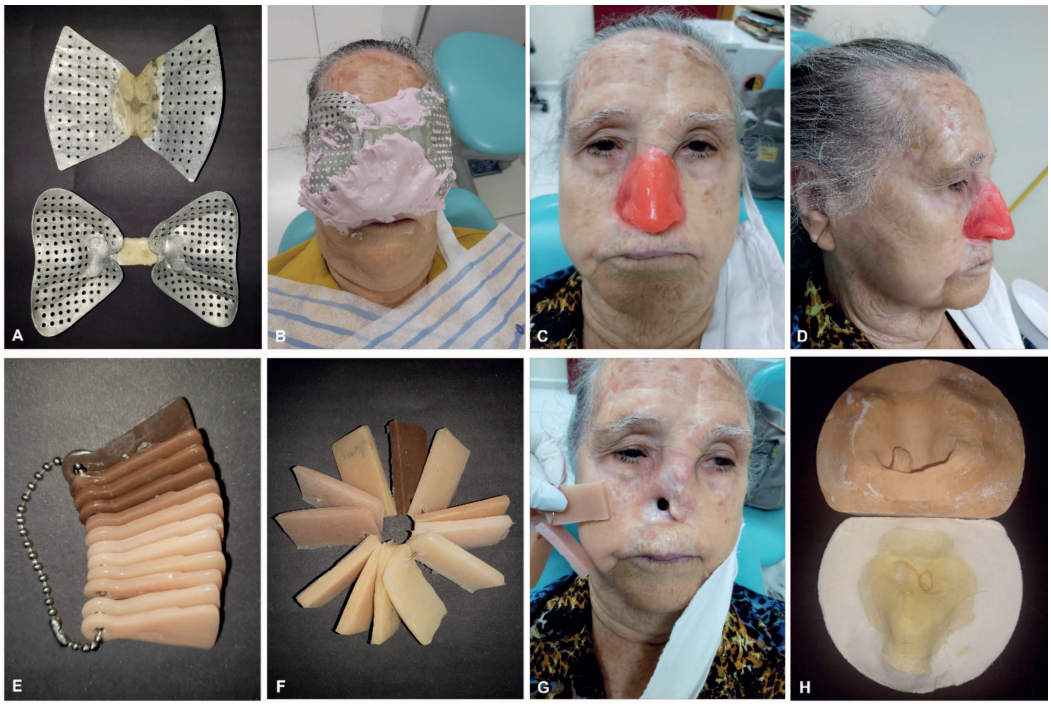

Figure 4: **A**- *Prefabricated perforated metal trays modified for molding of MFP;* **B**- *Molding with alginate;* **C**- *Frontal view of the waxed-up trail of the prosthesis;* **D**- *Right profile view of the waxed-up trial of the prosthesis;* **E**- *Customized colorimetric scale for intrinsic pigmentation of MFP made of acrylic resin;* **F**- *Customized colorimetric scale for intrinsic pigmentation of MFP made of silicone;* **G**- *Choice of the color for intrinsic pigmentation through the customized colorimetric scale;* **H**- *Inclusion of the model and the wax-up in muffle;*

Facial prosthesis (which involves the rehabilitation of the ocular region)

1. Registration of the patient's image, with Frontal and profile photographs;
2. Choice of size and color of the iris, and painting with acrylic paint (Acrilex) on prefabricated eye socket (Clássico) (Figure 5.A);
3. Wax-up of the ocular prosthesis with transparent wax 7 (Clássico), inclusion in a muffle with common plaster, removal of the wax and acrylization of the ocular prosthesis;
4. Make the facial prosthesis, following the same technique described above. The ocular prosthesis, previously made, must be positioned at the moment of waxing;
5. Choose the color for the intrinsic pigmentation (Figure 5.B). After the intrinsic pigmentation and vulcanization of the facial prosthesis (Figure 5.C), we continue with the characterization, through the insertion of eyelashes and eyebrow:
    a. Eyelashes: adaptation and gluing with transparent acetic silicone (Tekbond) of false eyelashes on the internal part of the prosthesis in the region of the mobile eyelid (Figure5.D);
    b. Eyebrow: insertion of synthetic hair, one by one, with a needle (40x1.2mm or 30x0.80mm), giving the size and shape similar to the eyebrow of the opposite hemiface;
6. Trial fitting of the prosthesis on the patient's face, adjustments and extrinsic pigmentation with make-up (following the same technique described for the nasal prosthesis), if necessary;
7. Application of the glue for Ultra Hold capillary prosthesis (Walker Tape) on the internal part of the prosthesis and positioning on the patient's face and delivery of the prosthesis.

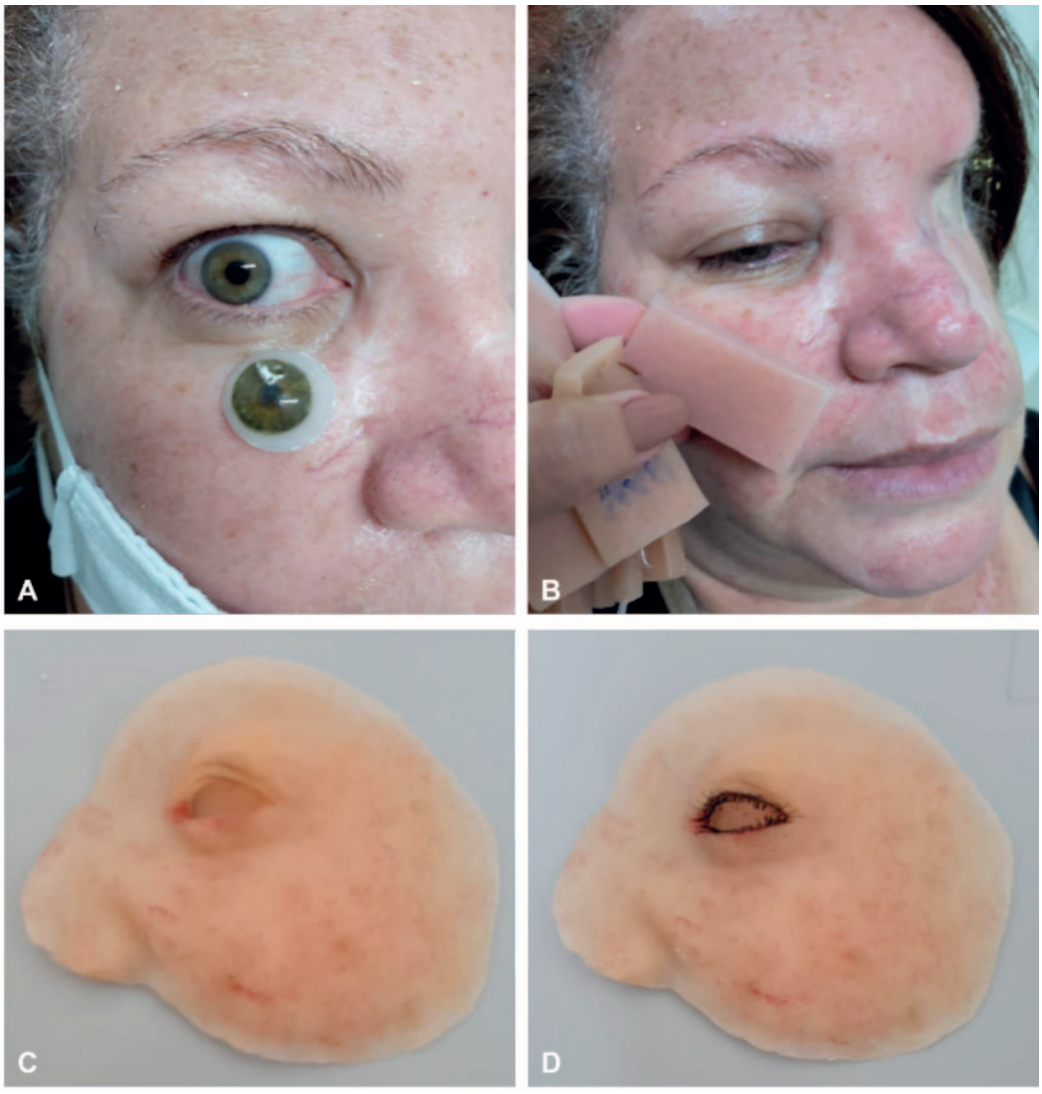

Figure 5: A- *Choice of size and color of the iris;* **B**- *Choice of the color for intrinsic pigmentation through the personalized colorimetric scale;* **C**- *Appearance of the facial prosthesis after intrinsic pigmentation and vulcanization;* **D**- *Appearance of the facial prosthesis after eyelash placement.*

Obturator prosthesis

1. Selection of prefabricated perforated tray (metallic or plastic);
2. Protection of the bucosinusal communication with moist cotton, aiming to reduce retention and the risk of tearing of the impression material and anatomical impression with alginate type II Avagel (Dentsply Sirona);
3. Disinfection of the mold with sodium hypochlorite and version in plaster type 4 Dent-Mix (Asfer) for making the study model;
4. Delimitation of the plating area and making of individual perforated tray in self-cured acrylic resin (Clássico);
5. Functional impression with the individual tray and condensation silicone;
6. Disinfection of the mold with sodium hypochlorite and version in plaster type 4 Dent-Mix (Asfer) for making the working model;
7. Confection of the base plate in self-cured acrylic resin (Clássico) and wax plans 7 red (Clássico);
8. Testing of the base plate with the wax planes on the patient and determination of the vertical dimension of occlusion using the Fox ruler and marking of the reference lines on the wax planes: midline, canine line/nose wing distance and high smile line;
9. Choice of tooth shade (Trilux scale) and mounting of teeth on the wax plane;
10. Testing the teeth mounted on the wax plane on the patient;
11. Inclusion in muffle with common plaster, wax removal and acrylization of the prosthesis with acrylic resin heat-curing (Clássico);
12. Finishing by removing excesses with burs and sandpaper, followed by polishing with pumice stone, cloth wheel and brush;
13. Testing of the prosthesis, adjustments and delivery.

DISCUSSION

The post-surgical rehabilitation is an essential part of the treatment plan - for functional, aesthetic and psychological issues - directly influencing the social life, reducing anxiety, improving self-esteem and quality of life of cancer patients (8,9). This rehabilitation can be done both through reconstructive surgeries and MFP (10).

The reconstructive surgeries, despite being a viable option and sometimes with satisfactory results, need specific conditions for its realization, being commonly contraindicated in cases with extensive losses, impairment of the patient's general condition, age extremes, economic limitations or even reluctance of the patient to undergo new surgical procedures (13). Moreover, in cases of surgery associated with adjuvant radiotherapy, the irradiated site becomes less vascularized, impairing the performance of reconstructive plastic surgery, since the area is altered, which males difficult the use of grafts (13).

On the other hand, MFP stand out and represent devices capable of reestablishing aesthetics and in some cases function. In addition, since they are removable devices, they allow direct observation of the surgical wound and, therefore, facilitate the observation of a possible disease recurrence (9). Among other advantages, they also allow for early rehabilitation, reduced hospitalization time, reduced use of nasoenteral tube, and consequently, decrease treatment cost (10).

The type and functionality of the MFP depend directly on the area that will be rehabilitated, and it can be: palatal obturator, nasal, facial, ocular, orbital, auricular or pharyngeal (9,10). The nasal, facial and orbital are key in protecting the surgical defect (14), thus avoiding the accumulation of residues in the region and the consequent development of secondary infections. In addition, they are essential in reestablishing aesthetics and its psychosocial consequences, as can be observed in the cases described.

The material for making the MFP will depend on factors related to the patient, the post-surgical anatomy, and the type of prosthesis. The ocular ones in particular can be made of glass or acrylic resin (polymetacrylate), the second one being the most used; the facial ones, of acrylic resin or silicone (11) and the obturators of acrylic resin. The fixation of these prostheses can be done only by anatomy or by means of auxiliary devices, such as magnets, implants, pericranial springs, adhesive, glasses frames, or even by the combination of more than one mean of retention (10,15). Thus, the choice of material should be made case by case, taking into account these variables and their respective advantages and disadvantages.

Facial prostheses made of acrylic resin are usually less expensive, more durable, and require less skill for correct positioning. However, because it is a more rigid material, they are less adaptable to facial movements, less aesthetic due to the shine generated by polishing, have thicker and more visible margins, and may easily fracture. Moreover, they generally require glasses for positioning and fixation (15), adding this cost for patients who do not use the device regularly. Such characteristics may hinder the patient's adaptation to the acrylic facial prosthesis, as observed in case 1.

Another material option for facial prostheses is silicone. It is gaining prominence, especially because of its easy handling and physical properties, such

as its stability when exposed to heat, its chemical inertness, its hydrophobicity, its repellency against organic materials, and its flexibility. Moreover, it is well tolerated by the mucosa and skin, allows the reconstruction of details, the making of thinner and less noticeable margins, and a greater similarity with the skin in terms of texture, brightness and color; it also allows a better adaptation of the margins, is relatively durable and resistant to friction (15). Another advantage is the possibility of extrinsic pigmentation with makeup, improving the aesthetics and masking the margins of the prosthesis.

Despite such advantages, silicone facial prostheses have a significantly higher cost, require the patient to use a specific glue (which also impacts the overall cost of the prosthesis), as well as manual dexterity for correct positioning and adaptation of the margins, which may represent an additional difficulty for elderly patients or those with motor difficulties (15). Furthermore, it is worth mentioning that sweating may interfere with the gluing power during use, and that some patients may present allergy to the glue fixative, which implies on the use of silicone prosthesis (15).

The average duration of the silicone MFP is usually from 8 months to 1 year (16), shorter when compared to the acrylic resin ones; although it does not fracture, as the acrylic does, it may suffer tearing and deterioration of the margins, colonization by fungus, pigmentation change and increase of the surface porosity, as observed in case 1. In this same sense, the importance of cleaning these prostheses should be emphasized: for it to be done properly, it is necessary to completely remove the skin and prosthesis layers, and this is not always possible (especially when the patient with MFP has less manual dexterity or less instruction), thus making the MFP more susceptible to fungal colonization and odor (especially in nasal prosthesis, in which moisture and secretion from the nasal cavity contribute to the development of this condition). Consequently, an ineffective cleaning results in a shorter durability.

As for obturator prostheses, their main function is to seal the bucosinusal communication and consequently, to prevent the passage of food and air, contributing directly to chewing, swallowing and phonation (9,10). In the case specifically reported, since the patient was edentulous, the dental elements were also included in the prosthesis, allowing, in addition to the filling of the oral sinus communication, the reestablishment of a solid diet. Moreover, the prosthesis also restored aesthetics, both by recomposing the smile and by the buccal volume and lip repositioning.

In this context, the insertion of the dental surgeon in the multidisciplinary oncology team is of fundamental importance, and these professionals are responsible for dental care before, during, and after oncological treatment, in order to prevent, diagnose, and treat oral toxicities (17). Included in this scenario are the dental surgeons trained by the multidisciplinary residency programs in oncology (18) and the specialists in MFP. According to the article 66 of the resolution 185 of Brazilian Federal Council of Dentistry, dated April 26, 1993, “the oral and maxillofacial prosthesis specialty has as objective the anatomical, functional and aesthetic rehabilitation, by means of alloplastic substitutes, of regions of the maxilla, mandible and face that are absent or defective as a consequence of surgery, trauma, congenital malformations or developmental disorders” (19). However, still in 2021, the same Council has only 64 professionals registered as specialists in this area (20).

Thus, the report of these cases aims to disseminate the use and importance of MFP to the general population, encouraging the search for qualified professionals, and allowing more patients to this benefit. Likewise, this study becomes relevant in the sense of making the academic, scientific and clinical communities aware of their role in the rehabilitation process of cancer patients using the MFP.

CONCLUSION

Through the three cases presented, this study shows that MFP are essential tools for restoring aesthetics and function (chewing, phonation, breathing and swallowing) in cancer patients, as well as contributing to psychological issues, the process of reintegration into society and improving the quality of life of these individuals. Therefore, since the dental surgeon is the professional responsible for making the MFP and monitoring these patients, the importance of their inclusion in the multidisciplinary oncology team in all phases of antineoplastic treatment and in the context of the MFP, with emphasis on postoperative rehabilitation, is highlighted.

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LITERATURE REVIEW

UNIVERSAL ADHESIVE SYSTEMS: A STATE-OF-THE-ART OVERVIEW

SISTEMAS ADESIVOS UNIVERSAIS: UM PANORAMA DO ESTADO DA ARTE

Edvaldo Fernandes Dos Santos[1], Maria Elisa da Silva Nunes Gomes Miranda[2], Cristiane Soares Mota[3]

ABSTRACT

Adhesive systems play a fundamental role in the adhesion of restorative materials to dental substrates. To make this adhesion more effective and long-lasting, these materials are in constant evolution, seeking to simplify the clinical steps and reduce the technique's sensitivity. The most recent generation of adhesives developed is the universal adhesives, which promise versatility and reduction of clinical steps. The aim of this study was to perform a literature review on universal adhesives and their characteristics. The literature review was performed by means of an electronic search in the Pubmed database. The literature shows that these adhesives chemically bond to tooth substrates and produce more stable and less hydrophilic dentin interfaces. However, some limitations exist when the use in self-etching mode is performed on enamel, and selective conditioning of this substrate is recommended. The use of these adhesives as a silane or primer in the cementation of glass-ceramics and metal alloys has also shown limitations. Nevertheless, in the cementation of zirconia-based ceramics and indirect composite resin-based restorations, the procedure can be simplified by the use of universal adhesives. Adhesive strength on dentin substrates under different conditioning modes varied between studies. As with any new material, long-term clinical evaluations are needed to demonstrate the efficacy of these universal adhesive agents, as reported in this literature review.

Keywords: Tensile Strength, Dentin Adhesives, Dental Materials.

RESUMO

Os sistemas adesivos têm papel fundamental na adesão de materiais restauradores aos substratos dentários. Para que esta adesão seja cada vez mais eficaz e duradoura, estes materiais encontram-se em constante evolução buscando a simplificação de passos clínicos e diminuição da sensibilidade da técnica. A mais recente geração de adesivos desenvolvida é a dos adesivos universais, os quais prometem versatilidade e redução de passos clínicos. O objetivo deste trabalho foi realizar uma revisão de literatura sobre os adesivos universais e suas características. O levantamento bibliográfico foi realizado por meio de uma busca eletrônica na base de dados Pubmed. A literatura mostra que estes adesivos ligam-se quimicamente aos substratos dentários e produzem interfaces dentinárias mais estáveis e menos hidrofílicas. No entanto, algumas limitações existem quando o uso no modo autocondicionante é realizado em esmalte, sendo recomendado o condicionamento seletivo deste substrato. O uso destes adesivos como silano ou *primer* na cimentação de cerâmicas vítreas e ligas metálicas também demonstrou limitações. No entanto, na cimentação de cerâmicas a base de zircônia e nas restaurações indiretas a base de resina composta, o procedimento pode ser simplificado pelo uso dos adesivos universais. A resistência adesiva em susbstrato dentinário sob diferentes modos de condicionamento variou entre os estudos. Como qualquer novo material, avaliações clínicas de longo prazo são necessárias para demonstrar a eficácia destes agentes adesivos universais, conforme relatado nesta revisão de literatura.

Palavras-chave: Resistência à Tração, Adesivos Dentinários, Materiais Dentários.

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INTRODUCTION

The adhesive procedures are in constant evolution since the introduction of the total acid etching technique by Buonocore in 1955 (1). Although a long-lasting and effective adhesion to enamel is already established, the demand for new techniques and materials still exists, since adhesion to dentin is still a complex and sensitive procedure, and there is also a demand for the reduction of clinical steps of acid etching, which tends to accelerate the appointment. In general, adhesives can be classified as total etching (conventional) or self-etching. This classification is made according to the form of demineralization of the tooth substrate and the treatment of the smear layer (2).

Conventional adhesives require acid etching of dental structures as a separate step, when there is a total removal of the smear layer (3), whereas the self-etching adhesives can modify the smear layer, simultaneously demineralizing and incorporating it to the dentin (4). In conventional systems, adhesion in enamel occurs by mechanical embrittlement, where the phosphoric acid increases the free surface area by creating microretentions, while in dentin there is a removal of the smear layer and exposure of collagen fibers due to demineralization (5). In this technique, the excessive drying of the conditioned dentin may cause the collapse of collagen fibers, leading to a deficient infiltration of the monomers present in the adhesive, which may reduce the bond strength (6).

In this sense, self-conditioning adhesives were introduced to eliminate the acid etching step, characterized by a highly sensitive step in the adhesive protocol. These adhesives condition and permeate the dentin simultaneously and are available in 1- or 2-bottle versions (3). In recent years, universal adhesive systems (UA) with a multimodal proposal have emerged. They are one step self-etching adhesives, which can be used with total acid etching, as self-etching or with enamel selective etching (7). Their differentials are the presence of functional monomers such as 2-methacryloyloxyethyl phenyl phosphate (Phenyl-P), 4-methacryloyloxyethyl anhydrotrimethyl (4-META) and 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP) which chemically interact with the hydroxyapatite of the dental substrates forming calcium salts (8), and the presence of silane in some brands, which promises to simplify the protocol for adhesion to ceramics (9).

Thus, the objective of this study was to conduct a literature review on universal adhesives and their characteristics.

LITERATURE REVIEW AND DISCUSSION

A literature survey was carried out by means of an electronic search in the Pubmed database. The terms used were: “adhesive” or “adhesives” and “universal”. The search was restricted to English language articles published between the years 2010 and 2021, except for three articles with publication dates prior to this interval for historical reference contextualization purposes.

Emergence of the UA

The UA represent the manufacturers’ attempt to introduce versatility by adapting a single bottle self-conditioning adhesive to other application modes without compromising adhesive efficacy (5). When compared to previous generations, the main advantage of these adhesives is the indication for a wide variety of restorative procedures and adhesion strategies. Besides, they have functional monomers that confer the capacity of chemical bonding to dentin hydroxyapatite, promising a more stable and durable adhesive interface (10).

Kuraray was the pioneer brand in the use of these monomers in dental materials. When its patent on the 10-MDP functional monomer expired around 2003, its potential was explored by other manufacturers. In October 2009, Bisco, Inc. launched a zirconia primer, Z-Prime™, containing 10-MDP in its composition. 3M ESPE, 2 years later, launched Scotchbond™ Universal, also containing 10-MDP in its composition. In the same year, Bisco, Inc. launched its first UA, All-Bond Universal® containing 10-MDP. Thus, it is visible that the introduction of phosphate esters is apparently part of the history of UA (11).

Although Scotchbond™ Universal (3M ESPE) is the first adhesive marketed with the concept of universality, functional monomers such as Phenyl-P and 10-MDP have been part of Kuraray’s adhesives and cements since the 1980s (11). An example of a 10-MDP monomer formulation is Clearfil SE Bond (Kuraray), which due to its high shear bond strength and great stability over time has become the gold standard of self-etching adhesives, the generation before universal adhesives (2). Such monomers (Phenyl-P and 10-MDP) were created by Kuraray in 1976 and 1981, respectively, and are currently widely used and disseminated in the UA currently available in the market (12). Some examples of these adhesives are described in table 1, and the role of these monomers, as well as their mode of action on dental substrates, will be further discussed.

TABLE 1. CHARACTERISTICS OF SOME UNIVERSAL ADHESIVES.

Brand	Manufacturer	pH	Functional Monomer	Silane	Composition
Scotchbond™ Universal (3M ESPE)	3M ESPE (St. Louis) Paul, MN, USA).	2.7 Ultra Smooth	10-MDP	Yes	BisGMA, 10-MDP, Vitrebond copolymer, HEMA, ethanol, water, silane, initiators
Futurabond® U (Voco)	Voco (Cuxhaven, Germany	2.3 Soft	10-MDP	No	Liquid 1 - BISGMA, HDDMA, HEMA, adhesive of acidic monomer, UDMA, 10-MDP, silica Liquid 2-ethanol, initiators, catalyst
All-Bond Universal (Bisco Inc.)	Bisco (Inc, Schaumburg, Il, USA)	3.2 Ultra Mild	10-MDP	No	Resins from dimethacrylate, HEMA, BisGMA, 10-MDP, ethanol, water, initiators
Clearfil™ Universal (Kuraray)	Kuraray (Tokyo, Japan)	2.3 Soft	10-MDP	Yes	Dimethacrylate resins, 10-MDP, BisGMA, 2-HEMA, silane, silica, camphorquinone, ethanol, water, initiators
AdheSe® Universal (Ivoclar© Vivadent)	Ivoclar Vivadent (Schaan, Principality of Liechtenstein)	2.5 Ultra Mild	10-MDP	No	10-MDP, HEMA, BISGMA, D3MA, carboxylated methacrylic acid

HEMA - 2-hydroxyethyl methacrylate; BISGMA - Bisphenol glycidyl methacrylate; HDDMA - 1,6-hydroxyethyl methacrylate; HPMA - 2-hydroxypropyl methacrylate; UDMA - urethane; 10-MDP -Metacryloyloxyethyl dihydrogen phosphate, D3MA-hydrophobic dimethacrylate; Source: elaborated based on Burke et al., 2017 (3) and Cardoso et al., 2019 (13).

Versatility of UA

In general, UA can be defined as bonding agents which work in any conditioning mode that the clinician considers appropriate. Depending on the clinical situation, the conditioning of the substrates can be total, partial (when only the enamel is conditioned) or used in a self-conditioning mode (3). Some systems contain silane in their composition to simplify the protocol of adhesion to ceramic restorations. Thus, the clinician would not need to apply a separate solution of a silane agent after the ceramic is prepared or etched with hydrofluoric acid (HF) (10).

However, there are *in vitro* studies that challenge the efficacy of combining adhesive and silane in the same bottle. Kalavacharla et al. compared conditioning protocols with and without the use of a separate silane agent, using Scotchbond Universal adhesive (3M ESPE), which the manufacturer informs silane in the composition. Lithium disilicate ceramics were tested, and following the preparation protocol recommended by the manufacturer, the specimens were conditioned with 5% HF for 20 seconds. The results showed lower adhesive strength in the group treated with UA itself than in the groups in which silane was applied prior to bonding. Thus, the authors stated that since silane and 10-MDP were not effective in optimizing the bond between ceramic and resin, silane should always be applied prior to bonding on lithium disilicate ceramics (14).

A systematic review with meta-analysis conducted by Cuevas-Suárez and co-workers indicated a limited ability of UA to achieve adequate and durable adhesion to glass-ceramics and metal alloys, as the bond strength was shown to be greater with separate use of the silane or primer. On the other hand, the same study established that cementation of indirect zirconia and composite resin-based restorations can be simplified with the use of UA, and the bond strength is similar or even better when compared to the use of silane or primers applied separately (15).

Regarding the use of UA with the various strategies of conditioning of dental substrates, we must consider that self-conditioning adhesives such as UA contain acidic conditioning monomers and permeators of these substrates, dispensing the conditioning step with phosphoric acid (16). According to their acidity, these adhesives can be classified as strong, when the pH is less than 1; strong intermediate, with pH ranging between 1 and 2; mild, when the pH is approximately 2; and ultra-mild, with pH being greater than 2.5 (17). The pH of most UA lies between the mild and ultra-mild ranges.

These pH ranges effect adhesion on dentin but may not be as effective on enamel, especially on intact enamel (11).

Thus, similar to the reports of these adhesives, a reduction in the bonding effectiveness to enamel can be expected when UA are applied in a self-conditioning strategy (18). Cardenas *et al.* suggest that active application (friction) and for a longer time is a strategy that ensures a better micromechanical interaction between UA and enamel. Comparing the phosphoric acid etching to the self-conditioning mode, their results indicated a gain in the degree of conversion, better retention pattern of the enamel and higher bond strength when the UA was actively applied for 40 seconds (19).

However, using microtraction tests to evaluate the adhesive strength, one study stated that enamel etching with phosphoric acid may not be crucial for the adhesion of UA, and that the active application of these adhesives in the self-conditioning strategy may be a practical alternative to selective enamel etching, considering only the adhesion aspect. In self-conditioning mode, 5 out of the 7 tested adhesives showed statistically higher degree of conversion and adhesive strength when actively applied. Moreover, each adhesive actively applied in a self-conditioning mode resulted in an average adhesive strength statistically similar to that obtained by applying the same adhesive to enamel conditioned with phosphoric acid (20).

Conversely, a systematic review with meta-analysis, updated in 2019, by Cuevas-Suárez and colleagues, pointed out that the bond strength of UA to enamel increases with prior conditioning using phosphoric acid, besides selective enamel conditioning is still indicated to achieve long-lasting and effective adhesion to this substrate (21).

Regarding dentin, phosphoric acid conditioning removes calcium, leaving behind a 2 to 5 µm-thick area of exposed collagen fibers. For some authors, it is unclear at this point whether, and how, UA containing the functional monomer 10-MDP are able to bind ionically to calcium-deficient treated dentin (22).

Campos *et al.* evaluated *in vitro* the adhesive strength of dentin conditioned with phosphoric acid prior to the use of UA in cementation of indirect composite resin restorations. Three different adhesives and the amine-free RelyX Ultimate cement were used. The results showed that the groups in which the dentin was acid etched presented significantly lower bond strength values in the push-out test. Hence, acid etching of the dentin significantly reduced the bond strength between UA systems and dentin in indirect restorative procedures (23).

Cardoso *et al.* evaluated the immediate bond strength and after 6 months of 5 UA applied in conventional mode or in self-conditioning mode. As a control group, gold standard adhesives were used, namely Scotchbond Multipurpose Plus (3M ESPE) and Clearfil SE Bond (Kuraray). The authors concluded that the performance of the UA is material-dependent, and most of the agents tested had stable adhesion to dentin with results similar to gold standard adhesives, especially in the self-etch mode. Nevertheless, there were no significant differences in bond strength between the strategies used. The authors suggested, though, that the self-conditioning mode produces more stable bonds, due to the observation of a smaller decrease in bond strength after aging. Thus, the authors recommend that the application of UA to dentin should not be preceded by phosphoric acid etching (13).

Another even more recent study comparing the effect of phosphoric acid on dentin prior to the use of a 10-MDP-containing adhesive with a 10-MDP-free adhesive from the same manufacturer revealed higher bond strengths for the 10-MDP-containing adhesive even in the group that acid etching was applied, showing important questions about the interaction between adhesives containing 10-MDP and their application on phosphoric acid etched dentin (24).

Functional monomers and chemical adhesion

10-MDP is a functional monomer common to most UA that ensures not only a micromechanical bond, through the hybrid layer, but also binds ionically to calcium through a hydrophilic group (Figure 1) present in the molecule (3). This chemical bond was first demonstrated in 2004 by Yoshida et al (25).

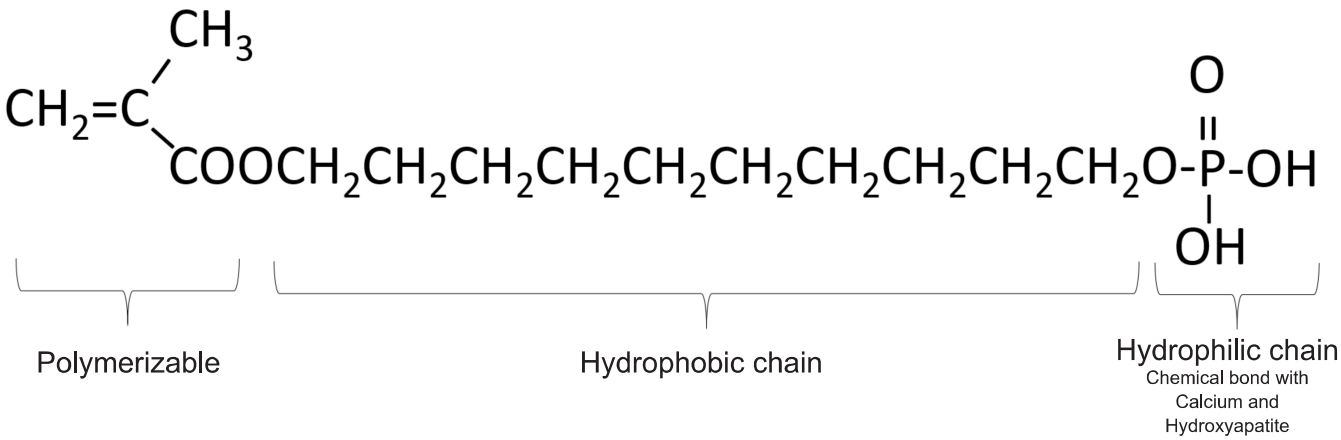

Figure 1. *Chemical structure of 10-MDP with its phosphate grouping (hydrophilic), its methacrylate grouping (polymerizable) and its long carbon chain (hydrophobic group).*
Source: adapted from Alex, 2015 (11).

When the adhesive containing MDP is rubbed onto dentin, the surface is partially demineralized to a depth of 0.5 to 1 µm. Calcium ions are released, due to a partial dissolution of the hydroxyapatite and diffuse into the hybrid layer and chemically bond to the MDP molecules forming nano-layers, as seen in Figure 2a. This process forms an MDP-Ca salt (26). These salts stay among the layers, and this is what holds them together (27). Theoretically the size of an MDP molecule is approximately 1.95 nm. Each of these nanolayers is made up of two MDP molecules, with their methacrylate groups directed towards each other and their phosphate functional groups directed away from each other. Thus, 3.90 nm is the approximate size of the nano-layer (Figure 2b) (28).

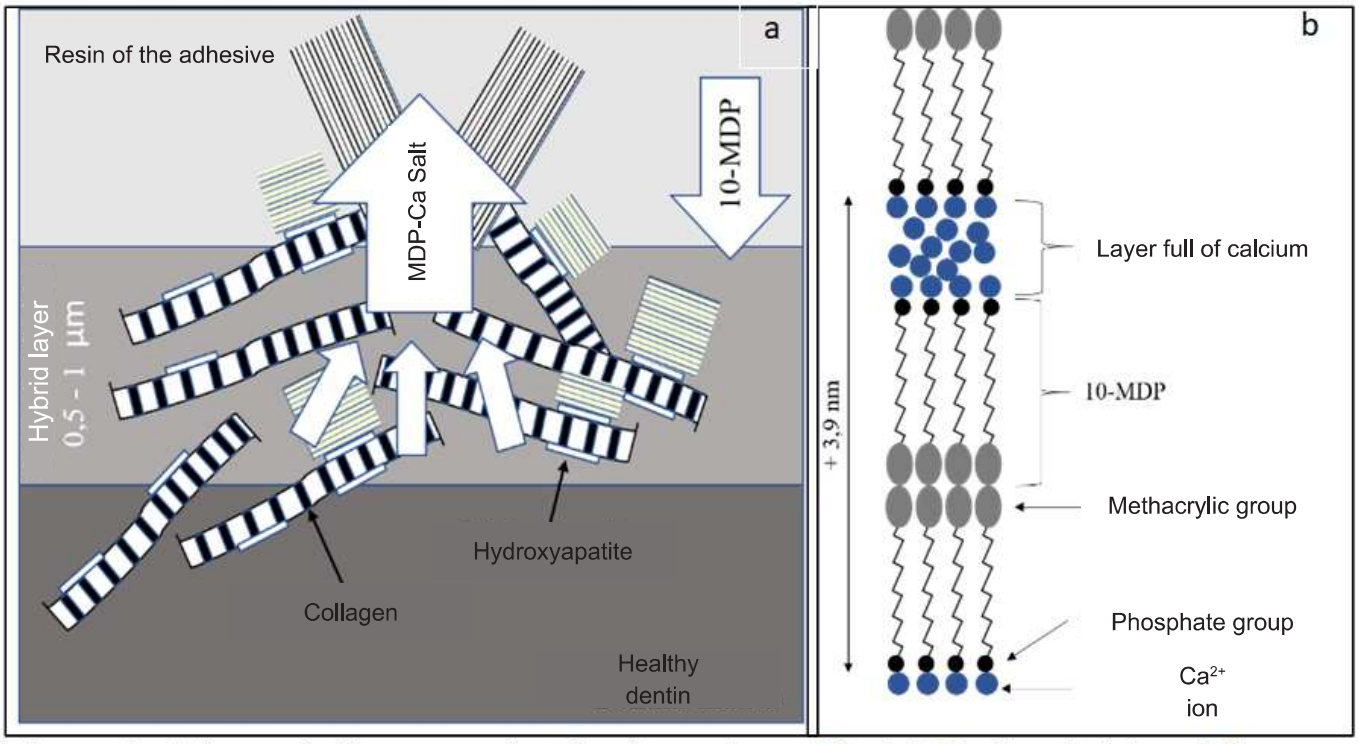

Figure 2. *Schematic demonstrating the formation of the MDP-Ca salt (a) and the nanolayers (b). Source: adapted from Yoshida et al. , 2012 (26).*

This nanolayer process is not identified with the functional monomers 4-META and Phenyl-P (27). Furthermore, data from previous studies comparing the adhesive efficacy of these three functional monomers revealed that the binding potential of 10-MDP to hydroxyapatite is significantly higher than that of 4-META, as an efficient chemical bond is achieved within 30 seconds. Only a strong binding potential is insufficient though. The ionic bonds must also be stable in an aqueous environment. In this sense, the chemical bond promoted by 10-MDP, besides being more effective, is more stable in water than that provided by 4-META and Phenyl-P, respectively. The dissolution rate of these calcium salts in the three monomers, as measured by atomic absorption spectroscopy, is inversely proportional to their chemical bonding potential. Thus, the more intense the binding power, the less soluble the resulting calcium salt will be (25).

Carrilho et al. stated in their systematic review that the selection of an UA system containing 10-MDP seems to be the safest choice due to its favorable molecular structure, hydrophobic behavior and adhesive interface characteristics that favor bond strength and durability. However, it recommends selective enamel conditioning to get the best out of these formulations and recalls the need for an active application on dentin. The clinician should allow time for the monomers to permeate, hybridize, and form the calcium salts that will protect the collagen fibers, improving adhesive stability (29).

Compatibility with chemical and dual-cure cements

Several reports have pointed out that simplified adhesives are incompatible with chemical and dual-cure resin cements, due to a reaction between the acidic monomers of these adhesives with the tertiary amines responsible for initiating the polymerization reaction of the cements. To circumvent this incompatibility, manufacturers of UA currently make polymerization activators separately. These activators are based on sulfinic acid salts and should be used with their adhesives whenever chemical or dual-cure cements are required. Some manufacturers also offer dual-cure cements free of tertiary amines, avoiding the use of separate activators, as is the case of RelyX Ultimate from 3M ESPE (3,30).

Most of the available literature on the incompatibility between simplified adhesives and dual-cure or chemical cements is based on the previous generation of self-etching adhesives. However, new adhesives with less hydrophilic and less water-permeable characteristics have been developed and are available on the market today. The addition of 10-MDP and its long carbon chain gives the UA interfaces with more hydrophobic characteristics than the previous generation (31).

Gutiérrez *et al.* after evaluating 3 UA used in the self-conditioning mode with dual-cure cements concluded that micro shear strength and nanoinfiltration were influenced by the different polymerization modes of the cements and the addition of polymerization activators, even though the authors stated that the influence was material-dependent (32).

In contrast, in 2020, Malaquias *et al.* evaluated, *in vitro,* 3 UA with polymerization activators added separately. The criteria tested were micro shear strength and nanoinfiltration when used in a total acid etching strategy and in association with dual-cure cements. The authors concluded that, in the total etching mode, the addition of polymerization activators to the UA and the different polymerization modes of the dual cements did not influence the micro shear bond strength. Regarding nanoinfiltration, some interactions were observed, which the authors also reported to be material-dependent (31). Based on this background, it is clear that further studies evaluating the incompatibility between dual-cure cements and UA are needed. The role of polymerization activators on the adhesive strength and the degree of conversion of dual-cure and chemically-cured resin cements is not yet well delineated in the literature.

CONCLUSION

This review pointed out that the UA are the adhesive class that seems to offer a more stable and durable dentin interface, due to the use of functional monomers. However, adhesive strength against different conditioning modes of this substrate was shown to be material-dependent in some studies while in others it showed no statistically significant difference. Thus, further studies are needed to elucidate the interaction of these adhesives with previously etched dentin. The literature has also shown that for adhesion to enamel, selective conditioning is still recommended to obtain maximum performance on this substrate. It was evident that the use of these adhesives in indirect procedures has limitations, and the separate use of a silane agent or primer is still recommended for glass-ceramics and metal alloys.

Incompatibility between UA systems and chemically or dual-cured cements appears to be resolved by the introduction of separate polymerization activators, but further studies are needed to evaluate the effects of these activators on adhesive strength to dental substrates and the degree of conversion of dual-cured cements.

The authors declare that they have no conflicts of interest.

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LITERATURE REVIEW

IS THE WHITE DIET NECESSARY DURING AND AFTER TOOTH WHITENING? A REVIEW OF THE LITERATURE

A DIETA BRANCA É NECESSÁRIA DURANTE E APÓS O CLAREAMENTO DENTAL? UMA REVISÃO DE LITERATURA

Isabella de Almeida Guimarães Passos[1], João Victor Frazão Camara[2]

ABSTRACT

The appreciation of aesthetics has become usual during dental treatment, with tooth whitening being one of the most sought procedures for the treatment of color changes and several authors consider that the white diet is important so that its aesthetic result is not compromised. However, other authors state that the ingestion of food and drinks with dyes does not interfere immediately and later in the result of the bleaching treatment. This article verifies, through literature review, if the white diet is really necessary during or after tooth whitening. A bibliographic search was performed in LILACS and PUBMED, and 16 articles were found that met the inclusion criteria. *In vitro*, *in situ* and *in vivo* studies exposed in this work report that there is no interference of pigments during bleaching on the result of the procedure. There is also a consensus that after the bleaching treatment, red wine interferes with color maintenance. Therefore, indicating the white diet is still a recommendation that is partially not based on scientific evidence, due to the lack of congruence in research results.

Keywords: Tooth whitening, tooth discoloration, pigmentation.

RESUMO

A valorização da estética tornou-se usual durante o tratamento odontológico, sendo o clareamento dental um dos procedimentos mais procurados para o tratamento de alterações na cor e diversos autores consideram que a dieta branca é importante para que o seu resultado estético não seja comprometido. Porém, outros autores afirmam que a ingestão de alimentos e de bebidas com corantes não interfere imediatamente e posteriormente no resultado do tratamento clareador. Este artigo verifica, por meio de revisão de literatura, se a dieta branca é realmente necessária durante ou após o clareamento dental. Foi realizado um levantamento bibliográfico nas bases LILACS e PUBMED, sendo encontrados 16 artigos que se enquadravam nos critérios de inclusão. Estudos *in vitro*, *in situ* e *in vivo* expostos nesse trabalho, relatam que não há interferência dos pigmentos durante o clareamento no resultado do procedimento. Há consenso também de que após o tratamento clareador, o vinho tinto interfere na manutenção da cor. Portanto, indicar a dieta branca ainda é uma recomendação que parcialmente não é baseada em evidências científicas, devido à falta de congruência nos resultados das pesquisas.

Palavras-chave: Clareamento dental, descoloração de dente, pigmentação.

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INTRODUCTION

The appreciation of aesthetics has become more and more usual by patients during dental treatment (1). Among the aesthetic concerns, the tooth color is one of the most reported, related to self-esteem and quality of life (2,3,4). In addition, whitened teeth have been attributed to more positive judgments about personality traits, such as competence and social appeal, intellectual ability, and relationship satisfaction (5).

The teeth color alteration can occur due to intrinsic factors and extrinsic factors (6). The tooth pigmentation caused by intrinsic factors may be the result of a range of factors, such as changes during tooth formation, systemic diseases, dental trauma, fluorosis and dental aging (6). The change caused by extrinsic factors can occur due to tobacco use, biofilm accumulation, use of drugs such as chlorhexidine and mainly through the ingestion of foods and beverages that have dyes in high concentrations such as coffee, red wine and cola-based soft drinks. (6,7,8). Correctly identifying the cause of the change in tooth color is essential to achieve and maintain a satisfactory result in the bleaching treatment (9).

Thus, the search for tooth whitening has become popular not only because of its range of indications for cases of altered tooth color, but also because it is a quick, minimally invasive, safe, and effective procedure (10).

During and after the whitening treatment, regardless of the technique used, the main question concerning the care that must be taken is about the use of drinks and foods that have dyes. Dentists commonly advise their patients to avoid foods and drinks with a high concentration of dyes, in order to obtain a satisfactory and lasting result (11). Several authors still consider that the white diet (diet without the ingestion of food and beverages with dyes) is important for the success of tooth whitening, so that the aesthetic result is not compromised (8,11,12,13). However, other authors state that the ingestion of food and beverages with dyes does not compromise the result (9,14,15,16). Thus, the aim of this study is to verify, through a bibliographic survey, if the white diet is truly necessary during or after tooth whitening.

LITERATURE REVIEW

A qualitative and bibliographic research was conducted on scientific articles about the use of the white diet during or after tooth whitening. The bibliographical survey was carried out in databases, such as Latin American and Caribbean Literature on Health Sciences (LILACS) and MEDLINE - Online System for Search and Analysis of Medical Literature, using the following Descriptors in Health Sciences (DeCS), registered in the Virtual Health Library (VHL) site: “Tooth whitening, tooth discoloration, pigmentation” in Portuguese and “Tooth whitening, tooth discoloration, pigmentation” in English. The search was made by combining the descriptors, using connectives such as “e/ou” in Portuguese and “and/or” in English. Inclusion criteria were full articles in Portuguese and English, published between 2008 and 2021. The exclusion criteria were publications that did not address the central theme of the study and publications in languages other than Portuguese or English. A total of 16 studies were selected, categorized in this review according to study design: *in vitro, in situ* or *in vivo*. Other publications were added for contextualization purposes and to suggest new studies.

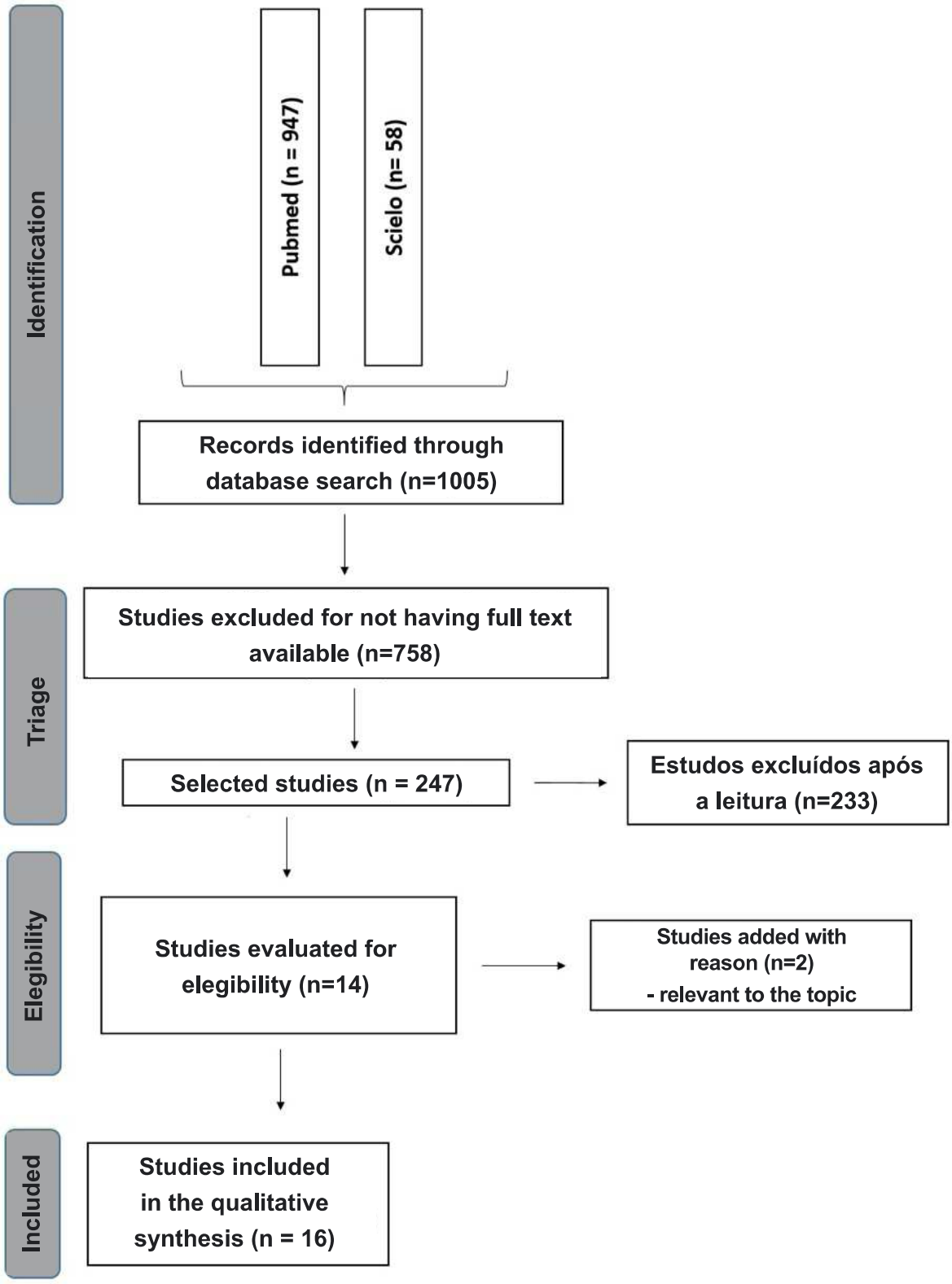

Figure 1. *Flow chart of the study.*

In vitro studies

Caneppele et al. bleached bovine incisors with 16% carbamide peroxide and divided them into 4 groups, which were soaked in coffee, wine or cola beverage for 5 minutes, twice a day. The control group was not submitted to imbibition in dyes. All teeth were kept in artificial saliva during the intervals of the experiment. At the end, the colorimetric values were obtained with the aid of a clinical spectrophotometer. There was no significant difference regarding the result of the bleaching treatment between the evaluated groups (14). Another study evaluating bovine teeth, 16% carbamide peroxide and coffee immersion (control group without immersion, experimental group immediately after bleaching and another experimental group 4 hours after) also observed no statistical difference between the evaluated groups (15). Another study evaluating bovine teeth, 16% carbamide peroxide and coffee immersion (control group without immersion, experimental group immediately after bleaching and another experimental group 4 hours later) also did not observe any statistical difference between the evaluated groups (15). Claudino et al. also did not observe any influence of pigmenting agents in bovine dental enamel on the result of immediate tooth whitening. This study evaluated the bleaching with hydrogen peroxide 35% in bovine teeth immersed for 15 minutes in distilled water, coffee, cola-based soft drink, wine, mate tea and industrialized açaí between bleaching sessions, which consisted of 3 applications of 15 minutes every 7 days for a total period of 21 days (17).

When evaluating the immersion of human premolars in distilled water, coffee, coffee with sugar, black tea, black tea with sugar, grape juice and grape juice with sugar, Rezende et al. observed no statistically significant difference between groups. The authors used 16% carbamide peroxide for 3 hours daily for 3 weeks and immersed the experimental groups for 5 minutes 3 times a day, and one of these exposures was performed immediately after tooth whitening. After 5 minutes of immersion in the staining solutions, the specimens were stored in artificial saliva at 37oC in an oven. In this study, home tooth whitening was effective even in the presence of food stains, regardless of the presence of sugar (16).

Correia et al. evaluated the effect of pigmenting agents on the color stability of bovine enamel fragments during tooth whitening. The blocks were divided into 7 groups: distilled water (control), coffee, cola, tea, red wine, chocolate milk and soy sauce. The 22% carbamide peroxide was applied for 1 hour a day for 14 days. After bleaching, teeth were exposed to solutions for 5 minutes. During the experiment, the samples were stored in distilled water. The color was evaluated before and after whitening (day 1 and 14) using a spectrophotometer. Only soy sauce promoted staining on whitened enamel while the other substances did not interfere with the tooth whitening treatment (9).

On the other hand, Azer et al. observed a statistically significant difference between teeth in the control group (immersed in neutral buffer solution) and teeth immersed in neutral buffer solution with red food coloring. The authors tested 20% carbamide peroxide bleach for 10h and immersion in the solution for 4h in recently extracted human molars and suggested that it may be beneficial to avoid highly pigmented foods immediately after bleaching (12).

Cortes et al. evaluated the influence of coffee and wine on human molar blocks obtained by bleaching treatment with 10%, 15% or 20% carbamide peroxide. The immersion in the solutions was performed for 15 minutes per day. The evaluation was done by spectrophotometer 3 times a week during the bleaching (22 days), and after the treatment for 7, 15 and 30 days. There was no difference between groups during the bleaching (different concentrations and different solutions). However, after bleaching, there were statistically significant differences between the groups immersed in coffee (day 30) and wine (day 7 and 30) in comparison with the control (13).

Another study used extracted human central incisors that were bleached with 10% carbamide peroxide for 6 hours a day for 2 weeks and in the intervals of the procedure, stored in artificial saliva at 37oC. After bleaching, the samples were divided into 5 groups according to the staining solution: artificial saliva (control group), red wine, coffee, cola-based soft drink and tea, and immersed for 15 minutes, 6 hours, one week and one month. No statistical differences were observed between the coffee and the control group, regardless of immersion time. The other groups showed a statistically significant difference with the control group. The cola-based soft drink presented the highest values after one week and one month of immersion (18).

Liporoni et al. evaluated bovine enamel fragments treated with 35% hydrogen peroxide and immersed 30 minutes or 150 minutes after bleaching in coffee and red wine. The authors also observed that coffee did not interfere with the bleaching result, although bovine enamel changed when immersed in red wine, regardless of the exposure time after bleaching (19).

Another study that observed changes in pigmented solutions after bleaching was conducted by Neri et al. Healthy human molars, sectioned in fragments, received bleaching treatment with hydrogen peroxide for 45 minutes, and the protocol was repeated 3 times. After bleaching, the specimens were immersed for 6 hours a day for 30 days. During the immersion

intervals, the specimens were kept in artificial saliva. The study showed that cola-based soft drinks, red wine, açai juice, coffee and black beer interfere in the stability of the whitened enamel color (20).

The action of fitness drinks (açaí, pink, green, yellow detox juices or water) in immersion for 1 hour daily in bleaching solution with hydrogen peroxide 35% in bovine enamel was evaluated in the study of Amorieli et al. The teeth that presented a difference in color change were the whitened teeth submitted to artificial aging with yellow and pink detox juice. On the other hand, the teeth that were not whitened had a greater change in color when submitted to the pink, açaí and green detox juices (8).

In situ studies

Fragments of bovine teeth were mounted in intraoral devices, submitted to tooth bleaching with 10% carbamide peroxide for 14 days and immersion in colored beverages for 10 minutes daily. The samples were divided into control (no bleaching + distilled water), positive control (bleaching + distilled water), bleaching + coffee, bleaching + grape juice. Volunteers used the device continuously, except during meals, oral hygiene, tooth whitening and pigment immersion. Evaluations were performed by spectrophotometer before whitening, on day 7 and on day 14. The treatment result was not affected by the immersion of the different substances, although it had influenced the different color dimensions: brightness and value (21).

Mori *et al.* evaluated human dental fragments mounted in intraoral devices bleached with 35% hydrogen peroxide and treated without contact with coffee, immersion in coffee solution for 30 minutes daily for 7 days, starting 1 week after bleaching and immersion in coffee solution for 30 minutes daily for 14 days, starting immediately after bleaching. The bleaching treatment was not affected by the daily exposure to coffee. The authors attribute the absence of difference between the groups to enamel remineralization due to contact with saliva (22).

In vivo studies

Rezende *et al*. evaluated 40 patients, dividing them into a control group (no intake of coffee and restricted intake of food with dyes) and an experimental group (consumption of coffee at least twice a day, performing 30-second mouth rinses 4 times a day and no food restriction). Both groups received a bleaching treatment with 16% carbamide peroxide for 3 hours daily for 3 weeks. The color was evaluated visually using the VITA scale and by spectrophotometer. Coffee exposure and non-white diet did not affect the degree of whitening compared to the control group (23).

Hass *et al.* performed whitening treatment with 35% hydrogen peroxide in 2 sessions with 3 applications of 15 minutes in 44 people, divided into a control group (no cola-based soda intake) and an experimental group (intake at least twice a day). Color was assessed visually using the VITA scale and spectrophotometer. The authors observed that exposure to cola-based soft drinks during in-office whitening treatments did not affect bleaching efficacy, even after 30 days of treatment (24).

Matis *et al.* evaluated five publications of in vivo studies that did not impose dietary restrictions. Patients answered questionnaires, being distinguished by whether or not they followed a white diet (consumption of coffee, tea, wine or dark fruits). It was observed that there was no interference in the bleaching result between the groups evaluated during the treatment (25).

DISCUSSION

This review included 16 articles with different methodologies, most of them *in vitro*, with only two articles presenting an *in situ* study design and three articles with an *in vivo* methodology.

Based on the *in vitro* studies, there was a difference in the conclusion of the results obtained between them. The discrepancy can be attributed to the immersion time of the stained solution of the experimental group (4 hours) in relation to 5 minutes of immersion in the study by Caneppele *et al.* and in the study by Rezende *et al*., and 15 minutes in the study by Camara *et al*. and Claudino *et al.* Moreover, despite not agreeing regard the coffee results, all the mentioned studies showed significant differences in the evaluation after bleaching in relation to wine and the control group (absence of pigment solution).

It was observed that several studies have evaluated the effect of colored beverages, such as wine, tea, coffee and soda, due to their high rate of consumption and because they are present in the diet of most of the patients. *In vitro*, *in situ* and *in vivo* studies exposed in this work, report no interference of pigments during bleaching in the result of the procedure. There is also a consensus that after the bleaching treatment, red wine interferes in the maintenance of the color. However, the other solutions and foods showed different results that may be due to different concentrations of pigments in the solutions and foods. This argument can also be hypothesized by the fact that solutions have different pH, and the more acidic (such as, for example, wine) the drink is, the greater is the degree of staining produced in the tooth structure when compared to substances with less acidic pH. (22).

This literature review also draws attention to the scarcity of studies in the form of a systematic

review, since this study is an important resource for the synthesis of scientific evidence, helping clinical professionals and researchers in their daily work. In addition, there is a scarcity of *in situ* and *in vivo* studies, with a predominance of *in vitro* studies. Another point that needs to be highlighted is the negative influence of electronic media and social networks, guiding and recommending dental products by individuals without professional legal registration or consent of the dentist.

In vitro studies have shown that the action of bleaching agents can interfere with enamel morphology, and when associated with the consumption of acidic beverages and tooth brushing, can cause severe damage to tooth structure (26-28). Another important aspect is a thin, inorganic, bacteria-free layer that forms under the enamel surface, protecting against acidic challenges. If the individual does not have adequate salivary flow, the acidic diet could modify enamel morphology and result in loss of outcome and/or longevity of tooth whitening. Therefore, further studies are needed to elucidate whether these and other factors may contribute to or exacerbate surface pigmentation during or after this procedure.

CONCLUSION

In vitro, *in situ* and *in vivo* studies exposed in this work, report no interference of the pigments during the bleaching in the result of the procedure. Though, there is a consensus that after the bleaching treatment, red wine interferes in the maintenance of the color. Thus, we conclude that there are still differences in the literature, and more studies must be conducted, especially systematic reviews compparing different methodologies. Still, indicating the white diet is a recommendation that is partially not based on scientific evidence, due to the lack of congruence in research results.

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LITERATURE REVIEW

FELDSPATHIC CERAMICS IN POSTERIOR TEETH BY CAD/CAM TECHNIQUE: A LITERATURE REVIEW

CERÂMICAS FELDSPÁTICAS EM DENTES POSTERIORES PELA TÉCNICA CAD/CAM: UMA REVISÃO DE LITERATURA

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ABSTRACT

The present study aims to evaluate the indication of the use of feldspathic ceramics in posterior teeth, by the CAD/CAM technique (Computer-aided design [CAD] and computer-aided manufacturing [CAM]), in a high demand treatment unit, through a literature review. An advanced search was carried out in the PubMed database, covering the last 15 years and using the following MeSH search terms: “dental crowns”, “CAD/CAM system”, “porcelain” and “review”. Thirty out of the 47 articles initially surveyed were selected to compose the final sample. From the present study, it was possible to conclude that the use of feldspathic ceramics developed by the CAD/CAM technique is safe in posterior teeth, whether the technique is respected. This technique is an excellent option for dental treatment in institutions of high restorative demand that have high levels of demand and readiness, promoting celerity, avoiding the use of temporary restorations, also reducing the number of urgencies in prosthesis.

Keywords: porcelain, dental crowns, computer-aided design, longevity.

RESUMO

O objetivo do presente estudo foi avaliar a indicação do uso das cerâmicas feldspáticas em dentes posteriores, pela técnica CAD/CAM (*Computer-aided design* [CAD] e *computer-aided manufacturing* [CAM]) *chairside*, em uma unidade de alta demanda, por meio de uma revisão de literatura. Uma pesquisa avançada foi realizada a partir da base de dados do PubMed, compreendendo os últimos 15 anos e utilizando os seguintes termos MeSH para pesquisa: “dental crowns”, “CAD/CAM system”, “porcelain” e “review”. Dos 47 artigos levantados inicialmente, 30 foram selecionados para compor a amostra final. A partir do presente estudo foi possível concluir que o uso das cerâmicas feldspáticas desenvolvidas pela técnica CAD/CAM é seguro em dentes posteriores, desde que respeitada a técnica. Esta técnica constitui-se em excelente opção para tratamento odontológico em instituições de alta demanda restauradora que possuem altos níveis de exigência e prontidão, promovendo celeridade, evitando o uso de restaurações provisórias, reduzindo também a quantidade de urgências em prótese.

Palavras-chave: porcelana, coroas dentais, desenho assistido por computador, longevidade.

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INTRODUCTION

Ceramic restorations obtained by CAD/CAM technology (Computer-aided design [CAD] and computer-aided manufacturing [CAM]) can also called chairside, when made in the dental office by the dentist, in a single appointment. This technique, developed in the 1980s, has become popular over the years and has brought restorative dentistry into a digital age (1,2,3).

The improvement of the software and hardware of the CAD/CAM equipment was accompanied by an improvement in the mechanical and optical properties of the materials available for milling. Ceramics that require additional sintering processes or glass infiltration in the laboratory do not qualify as chairside. On the other hand, feldspathic ceramic restorations that, with manual finishing and polishing, reach a satisfactory clinical level, can be fabricated in a single appointment. This category of materials combines the advantages of all-ceramic restoration, such as esthetics, biocompatibility, and durability, with the advantages of being manufactured in chairside mode, by the CAD/CAM system (short term, cost efficiency and quality control) (4, 5.6).

Although glass ceramics present better mechanical properties in vitro compared to feldspathic ceramics (7), Petridis et al.,did not report in their systematic review a statistically significant differences between the complication rates of feldspathic and glassy restorations (8). Furthermore, Wittneleen et al. in 2009 published a systematic review in which it was found that milled glass ceramics had a higher failure rate compared to feldspathic ceramics (9).

The literature has recommended the use of feldspathic ceramic in anterior single crowns, questioning its use in posterior ones (7,10,11). However, there is a lack of longitudinal studies on the longevity of posterior single-unit restorations when milling prefabricated feldspathic ceramic blocks. Lu et al., in a study published in 2018, found a success rate of more than 90% of milled feldspathic restorations after 3 years (1). Cerec Blocks®, Cerec Blocks PC® and Mark II® feldspathic blocks have flexural strength greater than 100 Mpa in vitro, satisfying the requirements of the ISO 6872/2008 standard for clinical use in posterior teeth. Added to this is the fact that the strength of such crowns increases after adhesive cementation (4, 12).

Dentistry in the Brazilian Navy deals with a complex and demanding system that requires a great number of care appointments with high levels of readiness, mainly regarding the dental treatment of their militaries. With the advent of CAD/CAM technology, new treatment options could be offered to a greater number of patients, quickly and resolutely, avoiding the use of temporary restorations, whose loosening can be problematic for the crew on board (13).

Restorations obtained by the CAD/CAM technique, in chairside mode, using feldspathic blocks can represent a revolution in the oral health care model, in terms of the prosthesis area, given the speed of the restoration process, without losing aesthetics and with cost reduction. Thus, a greater number of military personnel and their relatives can be assisted, increasing resolution and reducing scheduling.

In this sense, the purpose of this study is to evaluate the indication of the use of feldspathic ceramics in posterior teeth, by the CAD/CAM technique, in an institution of high restorative demand, through a literature review.

LITERATURE REVIEW

An advanced search was carried out using the PubMed database, looking for studies that could justify the indication of feldspathic restorations in posterior teeth, using the CAD/CAM technique. The research period comprised the last fifteen years and the MeSH terms used in the search using the boolean operator ”AND” were: “dental crowns”, “CAD/CAM”, “dental porcelain” and “review”.

An initial survey was carried out with 47 articles, which were reduced to 30 after an analysis of titles and abstracts. According to the exclusion criteria adopted, only articles published after January 2006 were considered. The full text of all articles of possible relevance was obtained for full reading.

Moreover, studies that focused on oral rehabilitation through dental implants were discarded. A potential article was discarded due to the risk of misinterpretation, as it was produced in Russian and only the abstract was translated into English.

The development of digital devices in the 1980s led researchers to study possible applications in dentistry. The objective was to provide clinicians, within the scope of private practices, with the possibility of scanning the tooth to be rehabilitated, creating a virtual model and milling the restoration from prefabricated ceramic blocks. The result of the process would be an indirect restoration that could be cemented in the same appointment, in a practical and fast way. As a result, the Cerec System® was developed in 1985 in Switzerland and was introduced to the market more widely in 1988 (2,5,14).

Currently, indirect all-ceramic restorations have been the main replacement for ceramic-coated metallic restorations in daily clinical practice (10). A wide range of materials has been used in the production of esthetic crowns, among them, feldspathic ceramic, the first to be used in dentistry, is also presented in powder and liquid form or in prefabricated blocks for milling. Other materials such as glass ceramics, based on leucite and lithium disilicate, are excellent options for indirect

restorations, given their high mechanical strength compared to feldspathic (5,15,16,17,18). Despite this, the difference among the clinical performance of these ceramics requires elucidation, since the adhesive bond to the tooth promotes an increase in the strength of restorations (12,19).

The choice of ceramic for each type of indirect restoration

Lambert et al. published a review in 2017 to guide the clinician in choosing the most appropriate ceramic for each type of CAD/CAM indirect restoration. According to the authors, no material has ideal clinical properties to be indicated as universal, with feldspathic blocks being more suitable for anterior teeth and those based on zirconia for infrastructure of posterior teeth (15). Besides, a meta-analysis published in 2018, based on eleven randomized trials and three prospective studies, pointed to a higher failure rate between single crowns and partial restorations tooth-supported made using CAD/CAM technology compared to those performed using the traditional technique. conventional (72 failures in 1209 restorations). The type of material and the technique used were the most frequent reasons for the failures that occurred. The study suggests that new research should evaluate the different generations and limitations of the existing CAD/CAM software, to better justify the presented failure rate (20).

Saglam et al. in an *in vitro* study published in 2021, after analyzing 20 endocrowns cemented in extracted teeth, concluded that polymer-infiltrated ceramic crowns presented higher fracture resistance compared to feldspathic crowns performed by the CAD/CAM technique (21). Aziz et al. argues that operator experience has no significant effect on the clinical performance of CAD-CAM lithium disilicate crowns evaluated over a 6-year study, opposing arguments on technical difficulty (16).

In contrast, a prospective clinical study that evaluated after 17 years 187 feldspathic ceramic restorations performed using CAD/CAM technology had a success rate of 88.7%, which is close to the success rate of gold restorations, reaffirming the indication of the use of such ceramics in daily clinical practice in posterior teeth. It is also important to note that three of the patients who presented multiple fractures were diagnosed with bruxism, which suggests that this specific group should be considered at high risk for this type of restoration (22).

Stona et al., 2015, after an in vitro study of ceramic restorations on implants, developed by Cerec®, found that feldspathics showed lower resistance to fatigue cycles performed in the laboratory compared to leucites and lithium disilicate. However, the three ceramics showed sufficient strength to withstand mastication forces after adhesive cementation (23).

Wittneben et al. (9) found in a systematic review on different types of ceramics milled using the CAD/CAM technique, that aluminum oxide-based ceramic restorations associated with magnesium oxide and resin-based composites presented a failure rate close to that of feldspathic ceramics. On the other hand, ceramized glass restorations had a greater number of failures. Despite this, the study showed success rates greater than 91.6% for CAD/CAM restorations after 5 years. Another systematic review published in 2012 indicated that feldspathic ceramic and glass-ceramized crowns had a clinical survival of more than 5 years with very low failure rates (8). In addition, after a systematic review of 55 articles on metal-free ceramics published in 2015, Sailer et al. reported a 90.7 to 96.6% survival rate of crowns 5 years after cementation (10). Following the same line of research, in a clinical study, in which 159 milled ceramic restorations (inlays and onlays) were evaluated, a success rate of 95.5% was found after 5 years, with no significant difference between CEREC Blocks® and IPS Empress CAD® (24).

Success of ceramic restorations

In 2016, Collares et al. created an online database in which 167 dentists between 1994 and 2014 could register the ceramic restorations produced in their daily clinical practice. 5,791 indirect restorations were cemented in 5,523 patients and followed up over the years, with the techniques used and possible failures always recorded online in Ceramic Success Analysis (CSA). Despite recognized biases, such as, lack of standardization of the material, the techniques used and the professionals invited, the study observed a high success rate of ceramic restorations with a failure rate of less than 1% per year in 15 years of follow-up. Risk factors for durability of all ceramic types were cervical depth of cavity preparation, presence of glass ionomer in the cement line and use of simplified adhesive systems. The authors also highlighted the difficulty in reaching expressive samples for the development of standardized clinical studies (25).

Klink et al. 2013 in their study, associated that the success of CAD/CAM restorations is associated more with patient factors and restoration type than with the adhesive protocol (18). Morimoto et al. published a systematic review on the survival rate of ceramic and resin inlays, onlays and overlays, finding a success rate of feldspathic restorations between 92 to 95% after 5 years and 91% in 10 years. The main causes of failure were the appearance of fracture or chip (26).

Currently on the market, the clinician has a wide range of options for prefabricated ceramic blocks for milling. Among them, Cerec Blocks® are manufactured from fine powder grains that produce a feldspathic ceramic almost free of porosities,

implying greater resistance and a better degree of polishing of the restorations (16). In addition, they are etchable using hydrofluoric acid, in order to create micromechanical retentions for adhesive cementation systems. The flexural strength of feldspathic blocks is approximately 112 or 120 MPa when polished or glazed, respectively (23). Added to this is the fact that milled ceramic blocks have greater resistance to fracture when compared to the traditional method (powder and liquid), as they have lower porosity and high concentration of crystals (16,27).

DISCUSSION

New technologies and materials are routinely introduced into dental practice. Ideally, clinicians should have evidence-based dentistry as a guide to a successful treatment plan (9). The present study aimed to carry out a literature review on the indication of the use of feldspathic ceramics in posterior teeth by the CAD/CAM technique and its applicability in an institution with high restorative demand. Nevertheless, obtaining a clear view of the mechanical properties of ceramics used by the CAD/CAM technique is difficult, due to the difficulty of standardizing research, testing methods and how the results are expressed (4,28,29). Studies on the clinical behavior of feldspathic and vitreous ceramics are lacking and it is necessary to conduct an extensive and detailed systematic review of these different types of ceramics, pointing out their failures and time of occurrence, which could generate integrated scientific evidence (19).

According to Nejatidanesh *et al*., the main cause of fractures of metal-free ceramic restorations followed in their study was the absence of the minimum thickness of material recommended by the manufacturer (24), which leads us to believe that the sensitivity of the technique may affect more the success rate of the works than the ceramic material itself, in contrast to the findings by Aziz et al. (16).

It is well known that is possible to compensate for technical sensitivity through immersive operator training by developing competence for the new procedure. The introduction of this technology in dentistry of the Brazilian Navy, compulsorily encouraged the development of training for dentists, who underwent a learning curve in the early years. As reported by Walker *et al*, most university graduates until 2009 did not receive any training on working with CAD/CAM (30).

It is noteworthy that despite having inferior in vitro mechanical properties compared to other ceramics, feldspathic blocks present a satisfactory clinical index of durability, presenting sufficient strength to withstand normal masticatory loads (8,10,14,22,23,25,26). Given the practicality of milling, which does not require the use of ovens for sintering or glazing, in addition to presenting sufficient aesthetics and strength, feldspathic ceramic blocks can be a good material option for public sector dental clinics that require productivity and speed to meet the high demand of patients.

One of the limitations of the present study was the lack of available studies on the specific topic under analysis. Another difficulty observed was finding articles that used the same standardized research methods. Variations in the choice of ceramic materials, types of restoration (inlay/onlay/crown/tabletops), reassessment time, positioning of the tooth in the arch, substrate evaluated, finishing and cementation form make it difficult to make a clear and fair comparison of the results obtained. More long-term prospective clinical studies with a significant sample of feldspathic ceramic restorations performed by the CAD/CAM technique on posterior teeth need to be developed.

CONCLUSION

The use of feldspathic ceramics developed by the CAD/CAM technique is safe in posterior teeth, as long as the technique is respected. It is an excellent option for dental treatment in institutions of high restorative demand that have high levels of demand and readiness, promoting celerity, avoiding the use of temporary restorations, also reducing the number of emergencies in prosthesis.

The authors declare no conflicts of interest.

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