

Clinical and Radiographic Effect of Minimizing Size of Stainless-Steel Crowns as Restoration for Pulpotomized Primary Molars

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Abstract

Aim

To evaluate and compare the clinical and radiographic performance of size-minimized versus standard stainless-steel crowns (SSCs) as full-coverage restorations for pulpotomized mandibular primary first molars.

Materials and Methods

This randomized controlled clinical trial adopted a split-mouth design in 18 children aged 4–8 years, providing 36 pulpotomized mandibular first primary molars. Each child contributed one tooth to each arm: a standard SSC on the control side (Group I) and a size-minimized SSC on the contralateral side (Group II). Minimization followed the vertical-cut, re-approximation, and welding technique. Crowns were assessed immediately after placement and at 1 week, 1 month, 3 months, and 6 months using the Modified United States Public Health Service (USPHS) criteria, the Gingival Index (GI) and Plaque Index (PI) at four surfaces of both the crowned tooth and its opposing natural tooth, standardized digital bitewing radiographs, and patient/parental satisfaction. Data were analyzed with the Mann–Whitney, Kruskal–Wallis, and chi-square tests ($p \leq 0.05$).

Results

Both groups showed a progressive, statistically significant intra-group improvement in gingival and plaque scores over the follow-up period, with no statistically significant difference between the minimized and standard crowns at any interval. All crowns in both groups retained Alpha ratings for retention, marginal adaptation, and freedom from fracture throughout (100% at every time point). Radiographic findings were normal in 100% of both groups, with no periapical or furcal pathology. Patient and parental satisfaction was uniformly high and comparable between groups ($p = 0.738$).

Conclusion

Within the limitations of this trial, size-minimized SSCs performed identically to standard crowns across gingival health, plaque accumulation, marginal adaptation, retention, fracture resistance, radiographic outcomes, and satisfaction. Crown-size minimization is a safe and clinically reliable option when a prefabricated crown is oversized relative to tooth morphology.

Introduction

Dental caries remains one of the most common chronic diseases of childhood and continues to pose a substantial clinical challenge, particularly in the primary molars. The anatomical characteristics of

primary teeth, combined with the difficulty of maintaining optimal oral hygiene in young children, mean that caries frequently progresses to extensive loss of tooth structure and pulp involvement. Restoring a severely decayed primary molar, especially after pulp therapy, calls for a durable full-coverage restoration that can protect the remaining tooth structure and preserve function until natural exfoliation.^{1, 2}

Stainless steel crowns (SSCs) have long been regarded as the treatment of choice in these situations because of their durability, ease of placement, cost-effectiveness, and consistently high success rates. Their capacity to provide complete coronal coverage and an effective marginal seal contributes substantially to the long-term success of pulp-treated primary teeth, and their longevity can extend from five to fifteen years when adequate marginal adaptation is achieved. Compared with conventional restorative materials, SSCs are particularly advantageous in the restoration of multi-surface cavities in primary molars.^{3, 4}

Despite these advantages, crown adaptation remains the critical determinant of clinical success. Poor marginal adaptation can promote plaque accumulation, gingival inflammation, cement dissolution, and compromised periodontal health; achieving an optimal fit is therefore essential for maintaining gingival health and ensuring restoration longevity.^{5, 6} Because SSCs are manufactured in standardized prefabricated sizes, variations in tooth morphology may leave the selected crown oversized relative to the prepared tooth.⁷ In such cases, crown modification becomes necessary most often when a tooth has been reduced below the smallest available crown, or when proximal caries has led to interproximal space loss.

Minimization of crown size is thus a practical and frequently necessary step in pediatric practice, aimed at reconciling standardized crown dimensions with an individual child's tooth morphology. The technique typically involves controlled crown reduction through a vertical cut, followed by re-approximation and welding of the crown margins. When properly performed, it can improve the marginal seal, reduce plaque retention, and support a favorable gingival response, all without unnecessary sacrifice of sound tooth structure.^{8, 9}

Nevertheless, the evidence directly comparing the clinical and radiographic outcomes of minimized versus standard-size crowns remains limited. Given how commonly clinicians modify crown size in daily practice, this gap is clinically meaningful. The present study was therefore designed to evaluate and compare the effect of crown-size minimization on gingival health, plaque accumulation, marginal adaptation, radiographic outcomes, and satisfaction in pulpotomized primary molars.^{9, 10}

Materials and Methods

Study design and ethical approval

This randomized controlled clinical trial employed a split-mouth design and was conducted between 2024 and 2025 at the Outpatient Clinic of the Pediatric Dentistry Department, Faculty of Dentistry, Suez

Canal University. The protocol was approved 641/2023 by the Faculty's Research Ethics Committee, and all procedures were carried out in accordance with the committee's guidelines. The purpose, potential benefits, and possible risks of the study were explained in simplified terms to each child and their caregiver, and written informed consent was obtained from parents or caregivers before any clinical procedure was performed.

Sample size calculation

The sample size for this study was a priori determined using G*Power software (version 3.1) ¹¹. Based on a two-tailed Wilcoxon-Mann-Whitney test, assuming a medium effect size (Cohen's $d = 0.435$), a significance level (α) of 0.05, and a desired statistical power ($1-\beta$) of 0.80 with an equal allocation ratio between the two groups, a minimum total sample size of 36 primary first molars. A total of 36 teeth were therefore obtained from 18 children, each child contributing two crowns one standard-sized and one minimized on opposite sides of the arch. The resulting sample size was consistent with previous work on this topic.¹²

Participant selection

Eighteen children with bilateral mandibular first primary molars requiring vital pulpotomy and full-coverage restoration were enrolled. A thorough medical history was obtained, and clinical examination under dental-unit illumination was performed to confirm eligibility.¹³

Inclusion criteria

Apparently healthy children (ASA I) free from systemic disease; cooperative behavior (Frankl rating III–IV); age 4–8 years; both sexes; symmetrical bilateral mandibular primary first molars clinically and radiographically indicated for vital pulpotomy and SSC restoration; sound, caries-free mandibular primary canines and second primary molars; mandibular primary canines with at least one-third of the root length remaining; and signed parental/caregiver consent.¹³

Exclusion criteria

Allergy to any study material; a history of spontaneous pain, intra-oral or facial swelling, fistula, or sinus tract; radiographic radiolucency, furcation involvement, or pathological bone loss; irreversible pulpitis or pulp necrosis; adjacent teeth requiring pulp therapy and a crown; a contralateral tooth on which the standard crown fitted without modification; and premature or early exfoliation of the mandibular primary canine or second primary molar.¹³

Grouping and randomization

Of 36 children initially assessed for eligibility, 18 fulfilled all criteria and completed the study, providing 36 mandibular primary first molars. Three children were lost to follow-up, six were excluded because adjacent teeth required pulp therapy and a crown, and nine were excluded because the standard crown fitted adequately without modification. In the split-mouth design, each child contributed one tooth to each group. After pulpotomy and tooth preparation, crown selection was performed: if the standard crown fitted adequately without trimming or contouring, the tooth was assigned to Group I (control side, standard SSC); if it was slightly oversized and required minor reduction to achieve optimal marginal adaptation, the contralateral tooth was assigned to Group II (study side, minimized SSC). Each group comprised 18 pulpotomized mandibular primary first molars restored in a single visit.

Clinical procedures

All children were examined clinically and radiographically, and behavior was managed using the Tell–Show–Do technique. Topical anesthesia (20% benzocaine) was followed by local anesthesia (lidocaine with 1:100,000 epinephrine). The selected tooth was isolated with a rubber dam, and vital pulpotomy was performed according to American Academy of Pediatric Dentistry (AAPD) guidelines: caries removal, access opening, coronal pulp amputation, hemostasis, application of diluted (1:5) formocresol for five minutes, placement of a zinc oxide–eugenol base, and full-coverage restoration.⁴

Tooth preparation followed AAPD recommendations for both groups.¹⁴ Occlusal reduction of approximately 1–1.5 mm was performed with a wheel stone in a high-speed handpiece to provide clearance without occlusal interference. Proximal reduction with a fine diamond bur broke the interproximal contacts while preserving maximum tooth structure. A feather-edge finish line was established approximately 0.5 mm below the marginal gingiva using a feather-edge diamond bur. Buccal and lingual surfaces were not reduced unless an excessive buccal bulge was present, and all sharp line angles were rounded to reduce stress concentration and facilitate crown adaptation.

For Group I, the appropriate crown size was determined by measuring the mesiodistal width of the tooth with a sterile digital caliper, and the crown was placed without modification once an adequate fit was achieved (Fig. 2).

For Group II, minimization was performed only when the selected crown was oversized. A mid-buccal reference mark was placed on the crown surface, and a vertical cut of approximately 2 mm was made from the gingival to the occlusal direction with crown scissors to create a V-shaped notch. The edges of the cut were re-approximated and overlapped by approximately 1 mm until an optimal fit was obtained, then welded with an S-U Dentafix welder. The margins were finished and polished with a large heatless stone followed by a rubber wheel to ensure smooth, well-adapted margins (Fig. 3).⁸

Before cementation, each crown was seated on the prepared tooth and lightly tapped until an audible click confirmed complete seating, and occlusion was verified. The tooth was cleaned and isolated with cotton rolls and Type I glass ionomer cement was prepared per the manufacturer's instructions, applied

to the internal crown surface, and seated under firm pressure. Excess cement was removed before initial set with a wet cotton pellet and, after setting, with a sharp probe to prevent gingival irritation. Occlusion was re-evaluated and adjusted as needed. Caregivers were instructed to avoid hard or sticky foods immediately after placement and were reinforced in oral hygiene measures around the crown and surrounding gingiva.

Evaluation methods

Each crown was assessed clinically and radiographically at baseline, immediately after placement, and at 1 week, 1 month, 3 months, and 6 months.^{15, 16}

Modified USPHS criteria

Restorations were evaluated using the Modified United States Public Health Service (USPHS) criteria, assessing four parameters: resistance to dislodgement (before cementation only), post-cementation retention, marginal adaptation, and fracture. Each was graded Alpha (excellent, no detectable issues), Bravo (satisfactory with minor issues), Charlie (noticeable deficiencies), or Delta (failure requiring intervention).^{17, 18}

Gingival and plaque indices

Gingival health was evaluated with the Gingival Index (GI)¹⁹ and Plaque Index (PI)²⁰ on both the crowned tooth and its opposing natural tooth. Four surfaces (mesiobuccal, distobuccal, mesiolingual, distolingual) were scored 0–3 and averaged for each tooth. Bleeding was assessed by gently probing the gingival sulcus parallel to the long axis of the tooth. Both indices were recorded at baseline and at each follow-up interval.

Patient and parental satisfaction

Satisfaction was recorded on a five-point Likert scale (1 = totally dissatisfied to 5 = totally satisfied) using a parental satisfaction questionnaire at baseline, 3 months, and 6 months, focusing on pain, mastication, bleeding on brushing, and food impaction.^{21, 22, 23, 24}

Radiographic evaluation

Standardized digital bitewing radiographs were obtained immediately after restoration and at each interval using a Fona X-ray unit and a reusable photostimulable phosphor plate (size 1), with a Rinn XCP holder to ensure consistent positioning (70 kV, 6 mA, 0.06 s). Interproximal bone level, crown margins, and the presence of pathological lesions were assessed, and radiometric analysis was performed with imaging software.²⁵

Statistical analysis

Data were tabulated and analyzed in SPSS version 26 (IBM Corp., Armonk, NY). Normality was checked with the Kolmogorov–Smirnov test. Descriptive statistics were expressed as mean ± standard deviation for quantitative data and as frequencies and percentages for qualitative data. The Wilcoxon Signed Ranks Test compared the two groups, the Kruskal–Wallis test compared time intervals within each group, and the chi-square test was used for qualitative comparisons. A p-value ≤ 0.05 was considered statistically significant.

Results

Eighteen children aged 4–8 years of both sexes completed the six-month follow-up, contributing 36 mandibular primary first molars. The two groups were comparable in age and sex, with no statistically significant difference in their distribution (Table 1).

Table 1
Demographic characteristics of the study sample.

Variable	Category	n	%
Sex	Male	10	55.6
	Female	8	44.4
Age (years)	Mean ± SD	6.4 ± 0.8	—
Tooth type	Primary first molar (D)	36	100
Total treated teeth	—	36	100

Gingival Index

Both groups showed a general decline in gingival scores over the follow-up period, consistent with progressive improvement in gingival health. At the mesiobuccal point of the crowned teeth (Table 2), the control group rose transiently from a baseline mean of 0.56 to 0.72 immediately after placement before declining steadily to 0.22 at six months, an overall statistically significant intra-group change (p = 0.04); the study group followed the same pattern, rising from 0.61 to 0.78 and then decreasing to 0.33 with a clear downward trend that did not reach significance (p = 0.09). Crucially, the wilcoxon test revealed no statistically significant difference between the two groups at any interval, and the overall between-group comparison was non-significant (p > 0.05). A comparable pattern was observed at the mesiolingual, distobuccal, and distolingual points, where the within-group reductions were frequently highly significant (for example, p = 0.04 at the mesiolingual point in the control group) but the between-group differences remained non-significant throughout.

Table 2
Mean Gingival Index scores of the control and study groups at the mesiobuccal point (Wilcoxon Signed Ranks Test).

Group	T1	T2	T3	T4	T5	T6	p (total)
Control (mean)	0.56	0.72	0.56	0.44	0.33	0.22	0.04*
Study (mean)	0.61	0.78	0.67	0.50	0.44	0.33	0.09
p (between)	0.531	0.865	0.416	0.814	0.431	0.495	0.859

*Baseline = before crown placement; Immediate = immediately after placement. *Statistically significant ($p \leq 0.05$).*

Plaque Index

Plaque scores fell steadily in both groups, with statistically significant intra-group improvement at all measured surfaces. Unlike the gingival index, plaque scores did not rise immediately after crown placement, since crowns were delivered clean and plaque accumulation requires time to develop. No statistically significant difference in plaque accumulation was found between minimized and standard crowns at any interval, indicating that crown-size reduction did not create plaque-retentive under-contoured areas.

Opposing natural teeth

The natural teeth opposing both the study and control crowns showed highly significant intra-group improvement in gingival and plaque scores over time ($p < 0.001$ at several sites). Between the crowned side and its opposing tooth, however, no statistically significant differences were detected at any interval (for example, overall $p = 0.749$ at the mesiobuccal point), indicating that crown-size modification did not adversely affect the periodontal health of the opposing dentition.

Modified USPHS outcomes

Both groups retained Alpha ratings for retention, marginal adaptation, and freedom from fracture at every follow-up interval, with no Bravo, Charlie, or Delta scores recorded (Table 3). No prosthetic complications, retention failures, or fractures occurred in either group throughout the study, and no significant intra- or inter-group differences were observed.

Table 3
Modified USPHS scores (Alpha ratings) in the control and study groups across all intervals.

Group	Baseline	Immediate	1 week	1 month	3 months	6 months
Control – Alpha	18 (100%)	18 (100%)	18 (100%)	18 (100%)	18 (100%)	18 (100%)
Study – Alpha	18 (100%)	18 (100%)	18 (100%)	18 (100%)	18 (100%)	18 (100%)

All Bravo, Charlie, and Delta scores were 0 (0.0%) at every interval; between-group $p = 1.00$.

Radiographic and satisfaction outcomes

Radiographic examination revealed normal interproximal bone levels, acceptable crown margins, and no periapical or furcal pathology in 100% of teeth in both groups throughout the follow-up period. Patient and parental satisfaction was uniformly high: in the control group, 10 participants (55.6%) were totally satisfied and 8 (44.4%) satisfied, while in the study group 9 (50.0%) were totally satisfied and 9 (50.0%) satisfied. No participant reported partial dissatisfaction, dissatisfaction, or dropout, and the between-group difference was not statistically significant ($p = 0.738$) (Table 4 and Fig. 4).

Table 4
Radiographic findings and satisfaction outcomes for both groups.

Outcome	Control n (%)	Study n (%)	p
Radiograph Normal	18 (100)	18 (100)	—
Radiograph Abnormal	0 (0)	0 (0)	—
Totally satisfied	10 (55.6)	9 (50.0)	0.738
Satisfied	8 (44.4)	9 (50.0)	

Discussion

Dental caries in the primary dentition remains the most prevalent chronic disease of childhood and frequently produces extensive, multi-surface destruction that conservative restorations cannot reliably manage. Full-coverage restorations are therefore often required to restore function, preserve arch integrity, and prevent further breakdown.¹ Stainless steel crowns have been advocated for more than six decades for badly broken-down primary molars, for teeth affected by developmental defects, and — most relevant here following pulp therapy. They are regarded as the gold-standard full-coverage restoration for primary molars because of their durable marginal seal, fracture resistance, and well-documented long-term success.^{2, 23}

Concerns about the biological effect of SSCs on gingival and periodontal tissues persist, but the literature consistently attributes gingival inflammation to improper crown adaptation, excessive marginal extension, and residual luting cement rather than to the crown material itself.^{5, 26, 27, 28} Because commercially available crowns are prefabricated in standardized sizes, they do not always fit primary molars with narrow mesiodistal dimensions or anatomical variations. This mismatch has traditionally been managed either by excessive tooth reduction or by seating an oversized crown, both of which may compromise periodontal health.⁷ Crown-size minimization, first described decades ago, was proposed precisely to resolve this dilemma by reducing excessive crown dimensions rather than removing additional tooth structure.⁸ Despite its long history and continued relevance, direct comparative evidence for minimized versus standard crowns has been scarce, which motivated the present trial.⁹

A split-mouth design using symmetrical bilateral first primary molars was chosen to equalize the oral environment, hygiene habits, and host factors between arms, thereby minimizing inter-subject variability.²⁹ First primary molars were selected to reduce variability in occlusal load and space-maintenance demands associated with second primary molars, allowing a more standardized comparison.³⁰ Sound, caries-free adjacent canines and second molars were required to avoid confounding the gingival and plaque assessments,³¹ and teeth with advanced pulpal or periodontal disease were excluded to ensure a homogeneous, pulpotomized sample.³² Where minimization was needed, the vertical-cut, re-approximation, and welding technique of Mink and Hill was used, followed by careful finishing and polishing to optimize marginal adaptation and limit plaque retention.^{8, 33}

Clinical assessment was standardized with the Modified USPHS criteria for their simplicity and reproducibility, complemented by the Gingival and Plaque Indices on both the crowned and opposing teeth and by patient/parental satisfaction, since treatment success reflects acceptance and comfort as well as clinical outcomes.^{16, 29, 34} Type I glass ionomer cement was selected over resin cement because it is less technique-sensitive, more tolerant of moisture, releases fluoride to counter recurrent caries, has a coefficient of thermal expansion close to that of tooth structure, and allows straightforward removal of excess all advantageous in pediatric patients.^{35, 36}

The slight rise in gingival index immediately after crown placement is consistent with the transient inflammation that tooth preparation and prosthesis seating can induce even in healthy tissues, and which typically resolves as the periodontium adapts.^{6, 16} Over the follow-up, gingival health improved and plaque scores remained stable or decreased in both groups, in line with reports of favorable periodontal adaptation when restorative technique and maintenance are sound.^{10, 37} No statistically significant difference in gingival index emerged between minimized and standard crowns at any interval; the overall improvement is best explained by proper marginal finishing and crimping, reduced cement remnants, patient adaptation to hygiene routines, and the low plaque affinity of a polished stainless steel surface.^{5, 6, 26, 35}

Plaque scores likewise fell steadily, with significant intra-group improvement and no between-group difference. Although minimization could theoretically create under-contoured, plaque-stagnant areas, this did not occur at any measured point – consistent with evidence that plaque accumulation around SSCs is driven by poor adaptation, residual cement, and inadequate hygiene rather than by crown size when the crown is properly crimped and polished.^{10, 38} The significant improvement in the opposing natural teeth, without any between-side difference, further indicates that minimization did not compromise the periodontal health of the opposing dentition; this improvement most likely reflects oral hygiene reinforcement and professional care rather than crown design.^{39, 40}

It should be acknowledged that some earlier studies reported transient increases in gingival and plaque indices during follow-up.^{10, 41, 42} Notably, comparisons of zirconia and stainless steel crowns have described an early rise in gingival scores that subsequently improved, with no difference between crown

types by six months suggesting that the initial inflammatory response is a temporary reaction to prosthetic placement rather than a material-specific effect.⁴³ The practical implication is that any restoration altering normal oral anatomy may affect gingival health if hygiene is neglected; close monitoring and continuous reinforcement of plaque control for both children and caregivers therefore remain essential.¹⁶

For marginal adaptation, both minimized and standard crowns maintained predominantly Alpha ratings for retention, adaptation, and freedom from fracture at every interval, with no prosthetic complications. These consistently favorable scores indicate that size reduction did not compromise mechanical or clinical performance, and that the welding process did not undermine structural durability – confirming that the modification is mechanically sound and clinically reliable.^{17, 18} Radiographically, normal interproximal bone height, intact crown margins, and the absence of pulpal or periodontal pathology throughout the follow-up indicate that both designs were well tolerated by the surrounding tissues, consistent with the excellent coronal seal SSCs provide for pulpotomized teeth.^{3, 4}

Patient and parental satisfaction was comparably high in both groups with respect to comfort, absence of pain, mastication, and freedom from food impaction. Esthetic concerns did not meaningfully affect satisfaction, likely because of the posterior location of the restored teeth, echoing reports that acceptance of preformed metal crowns is high once their functional benefits and longevity are explained.^{44, 45} Taken together, these findings support the null hypothesis: minimizing crown dimensions does not adversely affect biological or clinical outcomes and yields performance comparable to conventional crowns. This reinforces the principle that proper crown adaptation, rather than crown size per se, is the key determinant of gingival response and long-term restorative success.^{16, 41}

Limitations

Several limitations should be considered. Clinical and radiographic assessments relied on indices that, despite standardization efforts, may be subject to examiner bias. In addition, parental satisfaction and oral hygiene compliance were assessed subjectively and may have influenced the clinical outcomes. A larger sample and a longer follow-up period would strengthen the generalizability of these findings.

Conclusion

Within the limitations of this trial, size-minimized stainless steel crowns performed identically to standard crowns across gingival health, plaque accumulation, marginal adaptation, retention, fracture resistance, radiographic outcomes, and satisfaction. Both crown types produced a significant improvement in gingival and plaque indices over time within each group, with no significant difference between groups at any interval. Crown-size minimization can therefore be used safely when a prefabricated crown is oversized: it reduces excessive gingival impingement, avoids the need for over-trimming of tooth structure, and offers a practical solution when available crown sizes do not match

tooth morphology a benefit likely to be greatest in children with narrow mesiodistal dimensions or anatomical variations.

Declarations

Author Contribution

A.S.A.A. contributed to the study conception and design, participant recruitment, clinical procedures, data collection, interpretation of the results, and preparation of the original manuscript. M.S.M.S.A.F. contributed to the study conception and design, methodology, supervision, interpretation of the results, and critical revision of the manuscript. R.A.O.E. contributed to the study design, methodology, clinical supervision, data interpretation, and critical revision of the manuscript. A.S.A.A. prepared the figures and tables. All authors read and approved the final manuscript.

Data Availability

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

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Figures

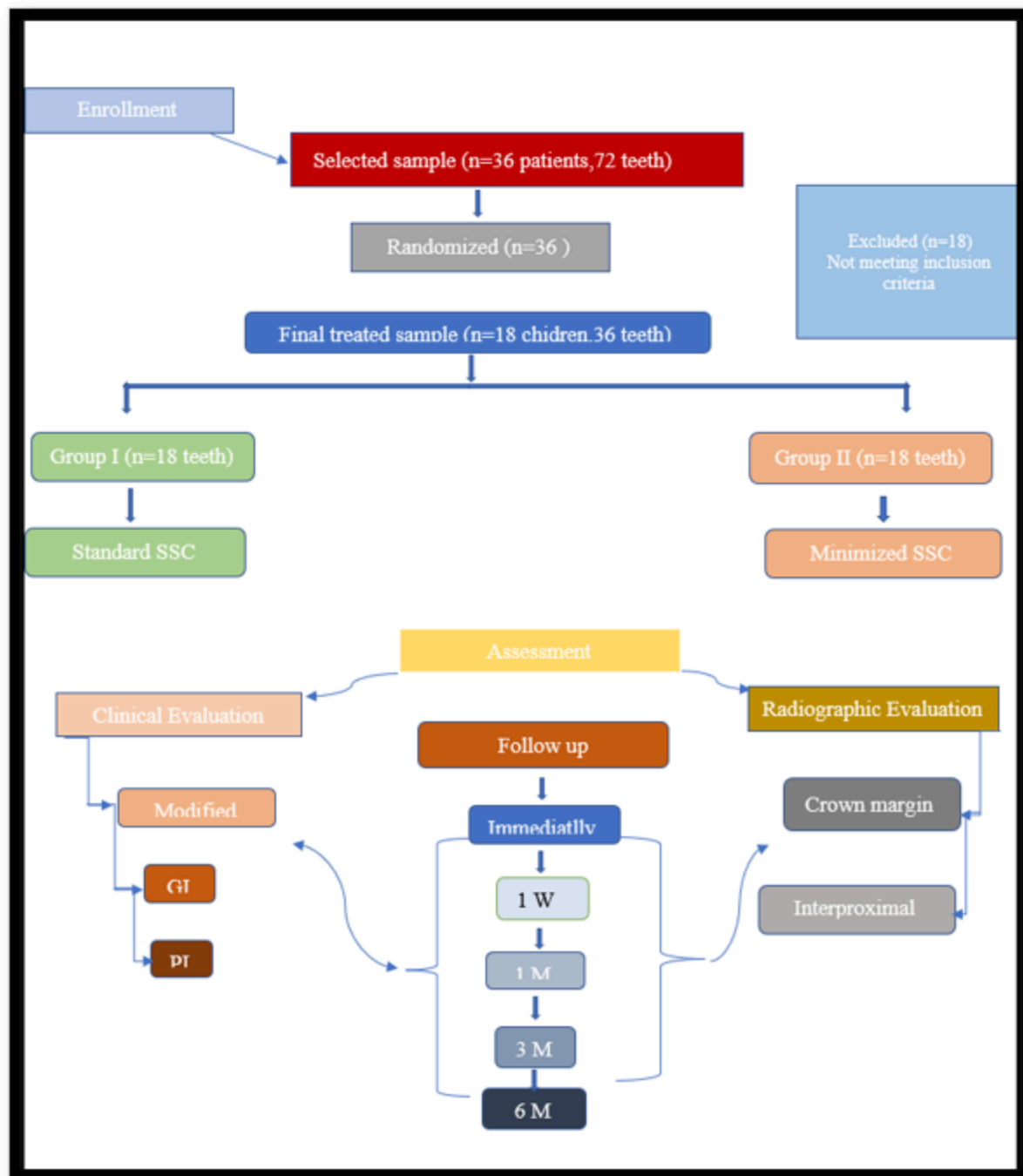


Figure 1

Flow diagram of the study. Of 36 children assessed for eligibility, 18 were excluded and 18 completed the trial, providing 36 mandibular primary first molars allocated by a split-mouth design to a standard crown (Group I) and a size-minimized crown (Group II).

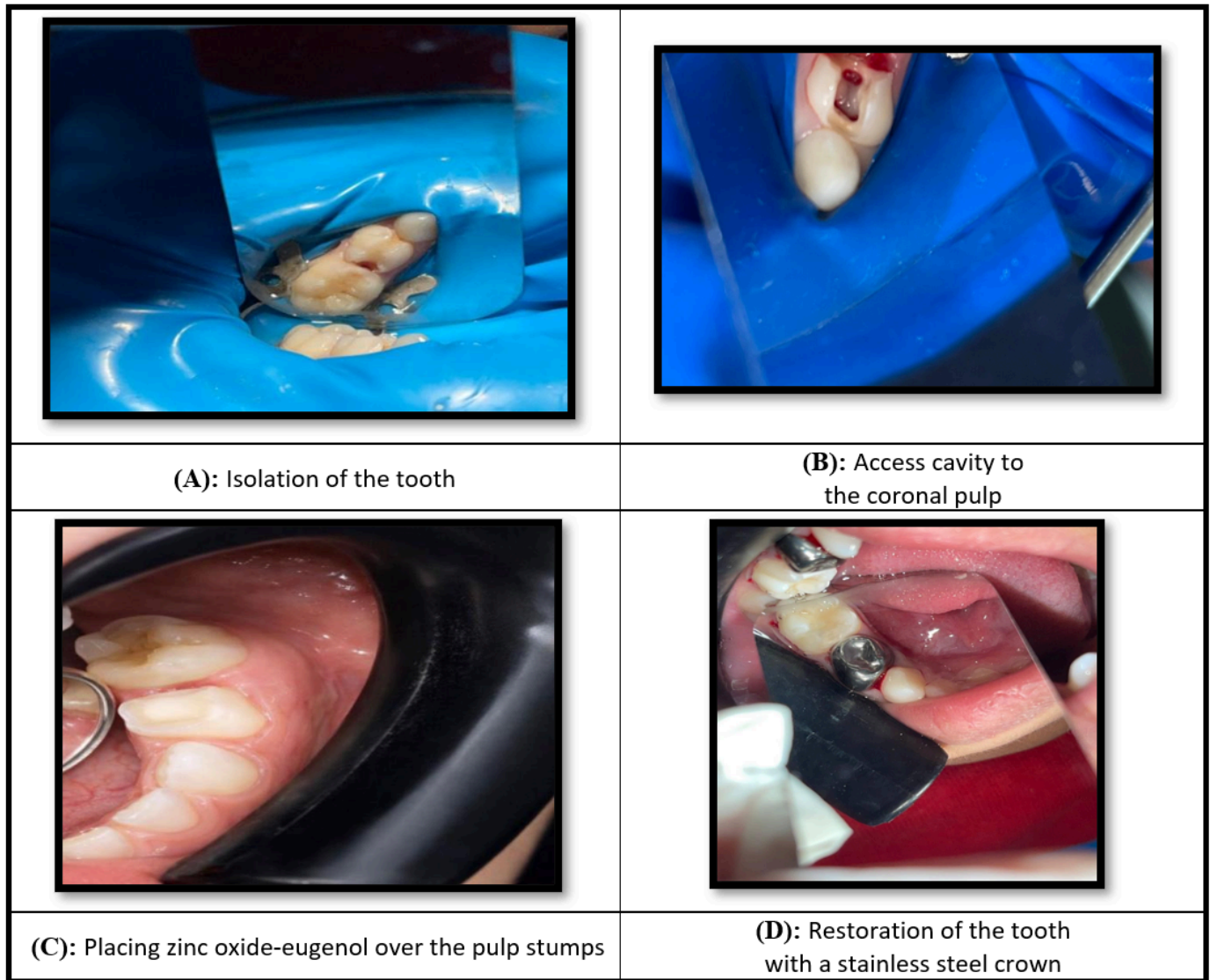


Figure 2

Vital pulpotomy and restoration sequence. (A) Rubber-dam isolation of the tooth; (B) access cavity to the coronal pulp; (C) placement of zinc oxide–eugenol over the pulp stumps; (D) final restoration with a stainless-steel crown.

	
(A): (2mm vertical cut)	(B): Reap the proximation of the edges of v shaped cut)
	
(C): Welding the edges of the V-shaped cut	(D): Crimping and contouring the stainless steel crown

Figure 3

Crown-size minimization technique (Group II). (A) A ~2 mm vertical cut from the gingival to the occlusal margin along the mid-buccal reference mark; (B) re-approximation and overlap of the V-shaped cut edges; (C) welding of the approximated edges; (D) crimping and contouring of the minimized crown to obtain an active fit.

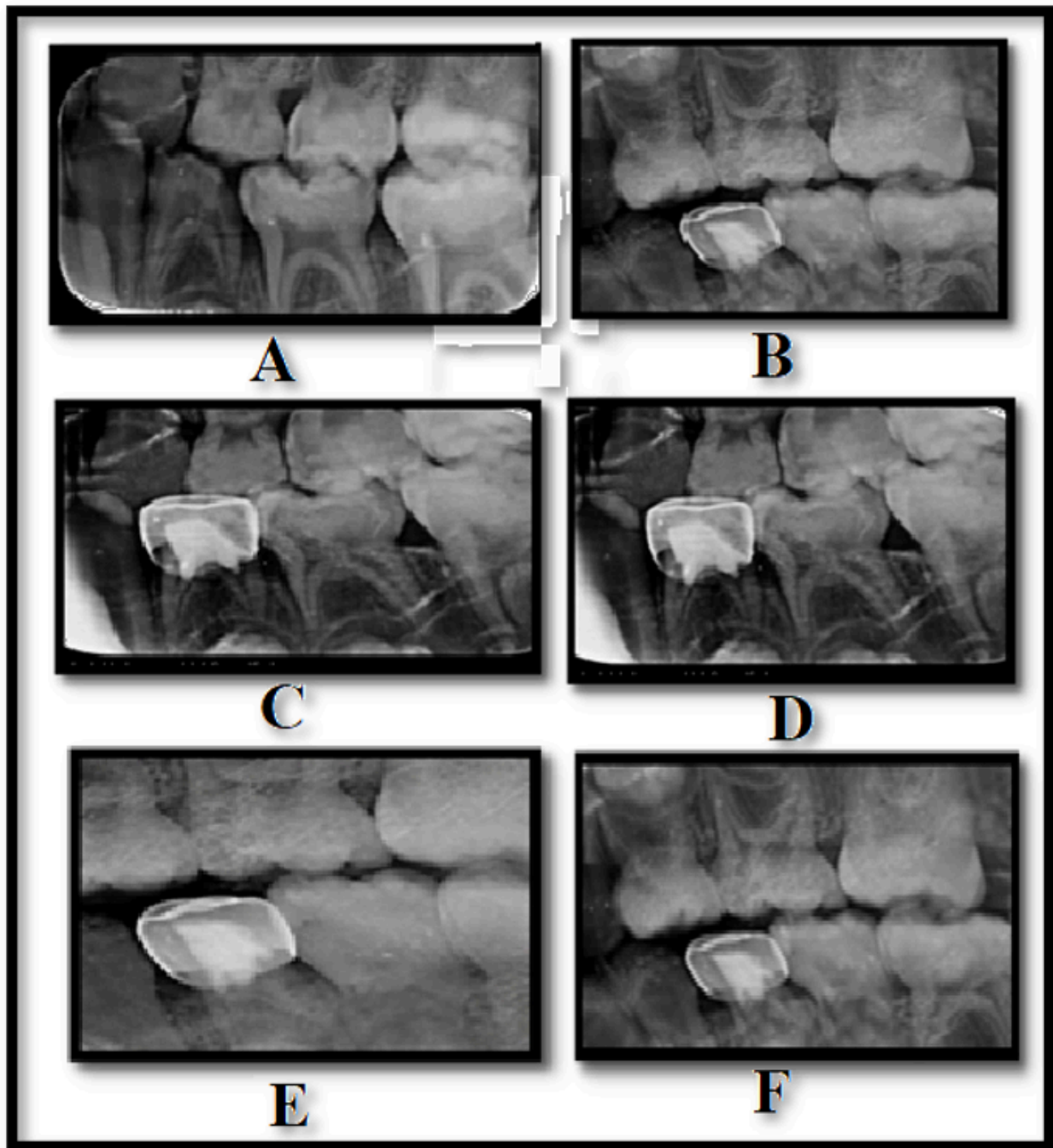


Figure 4

Serial bitewing radiographs of a minimized stainless-steel crown. (A) preoperative; (B) immediately postoperative; (C) 1 week; (D) 1 month; (E) 3 months; (F) 6 months. Interproximal bone level and crown margins remained normal, with no periapical or furcal pathology throughout the follow-up.