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Comparison Of Conventional Mbt Bracket Positioning Versus Smile Arc Protection (Sap) Bracket Positioning Technique And Their Effects On Smile Aesthetics And Dentition. A Prospective Clinical Trial

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Abstract
Aim of the study: *the aim of the study was to evaluate the changes in dentition and smile aesthetics between the patients bonded with mbt chart and the patients bonded with sap (smile arc protection) protocol by a prospective clinical trial.*
Materials and methods: *the study involved 72 patients split into two groups, each with 36 individuals. Group 1 brackets were bonded using the sap protocol, while group 2 underwent the mbt protocol. These groups were further divided into three subgroups based on arch length tooth material discrepancies: spacing, crowding, and well-aligned, with 7, 7, and 22 samples, respectively, in each subgroup. All patients were bonded with mbt 022 brackets, and initial leveling and alignment were performed until 19x25 niti wire. Monthly reviews were conducted, and preoperative and midoperative records were collected. A survey comparing changes in smile arc and smile display area between preoperative and midoperative stages was conducted among 19 orthodontists. The study assessed changes in various parameters between preoperative and midoperative stages within each group and subgroup. These parameters included the steepness of the occlusal plane, incisor inclination, intrusion/extrusion of incisors and molars, gingival display during smiling, incisal exposure at rest, smile display area, and smile arc which were measured in lateral cephalogram and frontal smile photographs. Statistical analysis was performed using the "statistical package for social sciences" (spss) software, version 26. Descriptive statistics, such as mean, standard deviation, and standard error of the mean, were used to express study variables. Intergroup comparisons were conducted using the independent samples t-test, while intragroup comparisons utilized the paired t-test. Correlations were assessed using either pearson or spearman correlation coefficients. A significance level of $p < 0.05$ was set for comparisons, and $p = 0.01$ was considered significant for correlation analyses.*
Results: *in well aligned subgroup, the incisor inclination of upper central incisor reduced significantly and tip of the central incisor moved more palatally in mbt than sap group. The occlusal plane rotated clockwise significantly*

in mbt group rather than sap group and gingival display increased significantly in sap group than the mbt group. In spacing subgroup, the smile arc showed significant improvement in sap group than the mbt group. There is no significant difference in extrusion or intrusion of incisors and molars between mbt and sap group in all the subgroups. Through correlations, it was found that percentage of consonancy introduced in this study seems to be a reliable in evaluating smile arc. Smile index can be used for identifying changes in the smile display area. Smile arc is significantly influenced by changes in the social smile. By comparing study parameters with growth pattern, it was found that vertical growers showed significant extrusion of incisors compared to horizontal growers.

Conclusion: *sap bonding can improve smile arc without significantly affecting dentition and occlusion. Care should be taken in preoperative examination of gingival display during smile and growth pattern of the patient. In this study, while the improvement in smile arc is minimal, further increasing the vertical distance between the bracket slots of upper anteriors according to samara protocol may enhance the smile arc. However, its effects on dentition need further research.*

Keywords*: smile arc protection, alignment and levelling, smile arc investigation, smile index, survey, dentition and occlusion, prospective clinical trial.*

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I. Introduction

Orthodontic treatment is often sought after primarily for aesthetic reasons. Understanding and addressing patients' aesthetic concerns is an integral part of orthodontics, reflecting a shift towards prioritizing facial beauty[1]. This emphasis on aesthetics dates back to the Angle era, where even an art professor, Wuerpel[2], contributed to teaching facial proportions to orthodontic students. Facial aesthetics are subjective and vary based on factors like ethnicity, geography, and individual psychosocial factors. The smile, being a central element of facial aesthetics, holds significant importance. A beautiful smile not only enhances appearance but also influences psychological well-being. Smiles can be categorized into various types, each reflecting different emotions and muscle movements[3-7]. Parameters such as smile line, arc, design, and tooth display contribute to smile aesthetics[8]. Orthodontists must consider these factors when devising treatment plans to ensure optimal aesthetic outcomes[9].

Smile arc, defined as the relationship between the curvature of upper incisors and the lower lip during a smile, is crucial for facial harmony[10]. Deviations from the ideal arc, such as flattening, can occur during orthodontic treatment due to bracket positioning and other factors. Historically, bracket positioning methods have evolved from placing brackets based on wire bending to more standardized approaches. Techniques like Andrews'[11] FA point and Ricketts'[12] marginal ridge approach aim to improve bracket placement accuracy. However, conventional methods often result in iatrogenic flattening of smiles.

To address this, novel bracket positioning protocols like Smile Arc Protection (SAP)[13-16] have been proposed. SAP considers smile aesthetics by positioning brackets gingivally in the upper incisors than the upper canines, preserving the natural smile arc[13-16]. In this study, we hope to get answers to the question: Is the SAP protocol suitable for MBT brackets, will it improve smile aesthetics, and what are the effects of gingivally placing upper incisor brackets in dentition and occlusion? We introduced a new parameter in the study called percentage of congruency. We would like to determine the reliability of this parameter and its clinical use. The primary objectives of the study were to assess improvement in smile arc between groups, examine changes in the steepness of the occlusal plane, and investigate the effects of SAP bonding on incisor inclination and position. Additionally, the secondary objectives involve evaluating the reliability of Smile Indices (SI[17], MSI[18] and VSP (Vertical Smile window Percentage) in reproducing posed smiles, assessing the reliability of Percentage of Consonancy/ Percentage of congruency in determining smile arc consonancy, analysing the effect of posed smile changes over time on smile arc consonancy, determining the sensitivity of various smile indices in detecting changes in posed smiles, and examining how study variables respond to orthodontic treatment based on individual growth and skeletal patterns.

II. Materials And Methods

This prospective clinical trial, conducted at the Department of Orthodontics, CSI College of Dental Sciences and Research, Madurai, from 2021 to 2023, involved randomly selected patients to mitigate selection bias. Institutional ethical approval (Ref No: CSICDSR/IEC/0242/2022, dated: 01.07.2022) and written patient consent were obtained.

Study Design: Prospective Clinical trial

Study Location: This clinical trial was done in Department of Orthodontics and Dentofacial Orthopaedics, at CSI College of dental sciences and research, Madurai, Tamil Nadu, India.

Study Duration: April 2022 to December 2023.
Sample size: 70 patients.
Sample size calculation: The sample size was estimated on the basis of a single proportion design. The target population from which we randomly selected our sample was considered 300. We assumed that the margin of error of 13% and confidence level of 90%. The sample size actually obtained for this study was 36 patients for each group. We planned to include 72 patients (Group I- MBT bonding, Group II- SAP bonding) with 2.8% drop out rate.
Subjects & selection method: The study population was drawn from patient seeking orthodontic treatment CSI college of dental sciences and research from April 2022 to March 2023. Patients were divided into two groups (each group had 36 patients) according to the bonding protocol followed.
Bracket placement protocol followed in the two groups are as follows:
Group I (N=36 patients) -Patients bonded with SAP bracket placement protocol; and
Group II (N=36 patients) - Patients bonded with MBT bracket placement protocol.

Inclusion Criteria:
- Patients with dental or skeletal malocclusion seeking fixed orthodontic treatment.
- Both sexes, aged 15 to 35 years.
- Symmetrical faces without severe dental or skeletal abnormalities.
- No history of previous orthodontic treatment.

Exclusion Criteria: Patients requiring maxillary tooth extraction for crowding.
- Systemic illness or medication.
- Congenital skeletal abnormalities or severe facial asymmetries.
- Congenitally missing upper anterior teeth.
- Periodontal conditions.
- Blocked out or impacted upper anterior teeth.
- Retroclined upper incisors or malformed teeth.

Armamentarium:
- MBT brackets with 0.022 x 0.028 slot.
- MBT and 3d printed - SAP bracket positioning gauges.
- ImageJ, Snapseed, Google Forms, Microsoft Photos, MS Excel, and MS PowerPoint.

Procedure Methodology:

Seventy-two patients were divided equally into two groups: Group 1 (bonded with SAP protocol) and Group 2 (bonded with MBT protocol) (Figure 1). Each group was further subdivided based on arch length discrepancy into Spacing (7 patients exhibiting spacing between their upper teeth), Crowding (7 patients with mild to moderate crowding) and Well-aligned subgroup (22 patients with either no spacing or minimal to no crowding in the upper arch). Standardized bonding and alignment procedures were followed using *Ormco^{TM} Mini-Diamond Twin* brackets, *3M™ Transbond™ XT Light Cure Adhesive and G&H Orthodontics^{R} wires,* utilizing MBT or SAP protocols (Figure 2). Intrusion mechanics were deferred until midop stages.

Height of clinical crown of upper canine is taken as reference and half of the measurement was calculated and labelled as X. The vertical height of bracket placement for both the protocol is calculated by

GUIDE for maxillary arch	Central Incisor	Lateral Incisor	Canine	1st Premolar	2nd Premolar
MBT protocol	X	X – 0.5mm	X	X – 0.5mm	X – 1mm
SAP protocol	X + 0.5 to 0.75mm	X	X	X – 0.5mm	X – 1mm

Similarly for lower arch,

GUIDE for mandibular arch	Central Incisor	Lateral Incisor	Canine	1st Premolar	2nd Premolar
MBT protocol	X – 0.5mm	X – 0.5mm	X	X – 0.5mm	X – 1mm
SAP protocol	X – 0.5mm	X – 0.5mm	X	X	X – 0.5mm

Photographic and Cephalometric Records: Pre- and mid-treatment records were obtained for all patients (Figure 3). Smile arc congruency percentage were assessed by an external examiner.

Figure 1 – Represents the lines depicting Bracket position for both MBT and SAP protocol

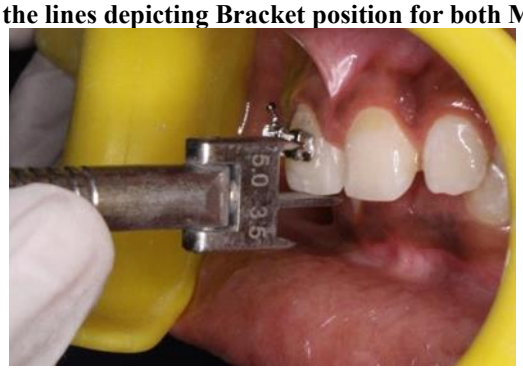


Figure 2 – Bracket positioning by SAP protocol during bonding

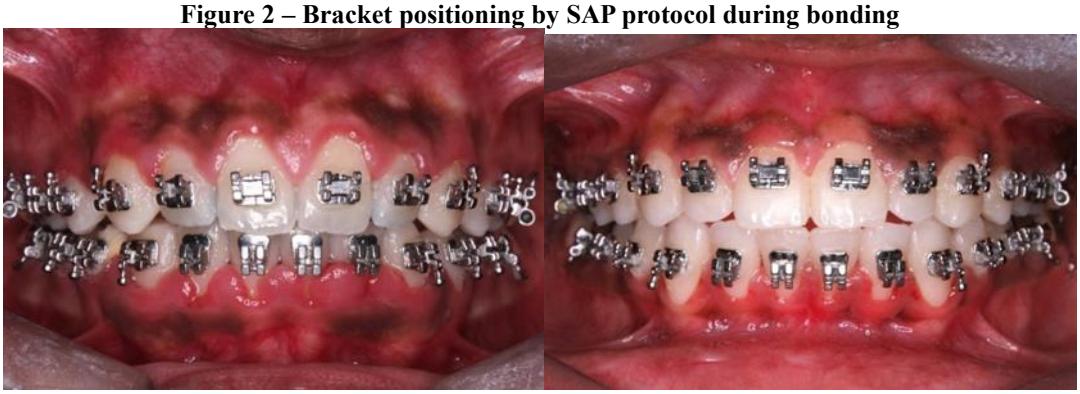
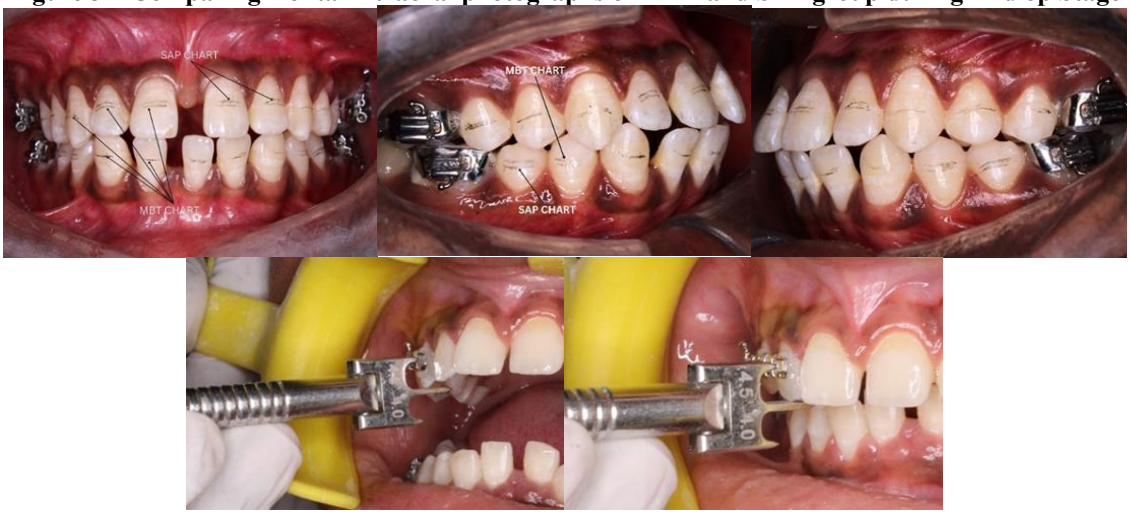


Figure 3 – Comparing frontal intraoral photographs of MBT and SAP group during Mid op Stage



MBT SAP

Measurements:

- Skeletal and soft tissue parameters.
- Smile arc consonancy using percentage of consonancy, smile display area using smile indices (Modified Smile Index[18], Smile Index[17] and Vertical Smile window Percentage (VSP)), and gingival exposure during smile were recorded using Image J software.
- For Percentage of consonancy (POC), 40 x, y coordinates or boundary points[19] of incisal edges of upper anteriors and 40 x, y coordinates of upper border of lowerlip were recorded. Polynomial regression analysis was done to obtain a best fit curve[19] and two quadratic equations were obtained. Coefficient of the quadratic term(x^2) 'a' was tabulated and POC was calculated as

$$\%\ of\ consonancy = \frac{Coefficient\ of\ quadratic\ term\ of\ the\ \ incisal\ edges\ of\ upper\ teeth}{Coefficient\ of\ quadratic\ term\ of\ upper\ border\ of\ the\ lower\ lip} \times 100$$

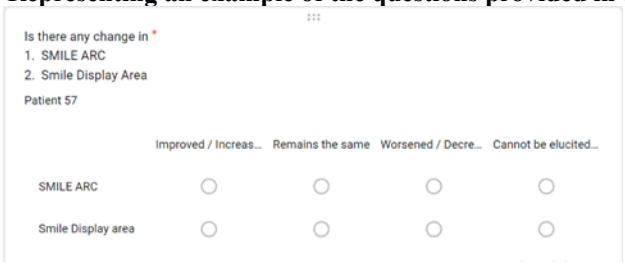
$$VSP = \frac{Inter\ labial\ gap\ during\ smile\ at\ midline}{Intervermillion\ distance\ during\ smile\ at\ midine} \times 100$$

- Cephalometric parameters (SN to Palatal plane, SN to Occlusal plane, Palatal plane to Occlusal plane, Pn to Occlusal plane, Upper incisor (UI) to SN plane, UI to Palatal plane, UI to NA angle, UI to NA distance, UI exposure at rest (UI to upper lip), Perpendicular distance from Palatal plane to 1) tip of UI, 2) Anterior most point of CEJ of UI, 3) CR (Centre of resistance) of UI and 4) Furcation of Upper first Molar) compared between pre- and mid-treatment stages traced by single examiner using lateral cephalogram.

Survey:

A survey involving 19 orthodontists was conducted about smile arc and smile display area changes for all the patient during treatment (Figure 4). Preop and Midop photographs were displayed in the projector. The most commonly chosen responses were tabulated for analysis.

Figure 4 – Representing an example of the questions provided in the survey



Statistical analysis:

The collected data were entered into Microsoft Excel spreadsheet and was subjected to statistical analysis by using SPSS software, IBM, version 21. The descriptive statistics was performed for the distribution of study population in the study, with respect to age, gender and diagnostic parameters.

Inferential statistics was done after checking for the distribution of study data by using Kolmogrov Smirnoff test which normality was checked and finally parametric and non-paramedic test would be applied.

Accordingly, the comparison between the intergroup factors were analysed using the ANOVA test or Kruskal wallis test and correlation between the factors will be done by Pearson correlation coefficient or Spearman's correlation coefficient test and for inter group comparison independent t test or Mann Whitney will be performed and for intra group time depended comparison paired t test will be performed in which the statistical significant difference was kept as P value less than or equal to 0.05 as a significant difference among the parameters.

The obtained statistical parameters output will be inferred clinically respectively.

III. Results

Baseline Data Summary:

- Age range: 11 to 30 years, with a concentration around 20 ± 5 years.
- MBT group: 12 males (34.3%) and 23 females (65.7%); SAP group: 17 males (48.6%) and 18 females (51.4%).
- Skeletal patterns: MBT - Class I (48.6%), Class II (51.4%); SAP - Class I (54.3%), Class II (45.7%).
- Grower types: MBT - Horizontal (37.1%), Vertical (20.0%), Neutral (42.9%); SAP - Horizontal (31.4%), Vertical (25.7%), Neutral (42.9%).
- Smile types: Cuspid (71.4%), Monalisa (24.3%), Complex (4.3%).

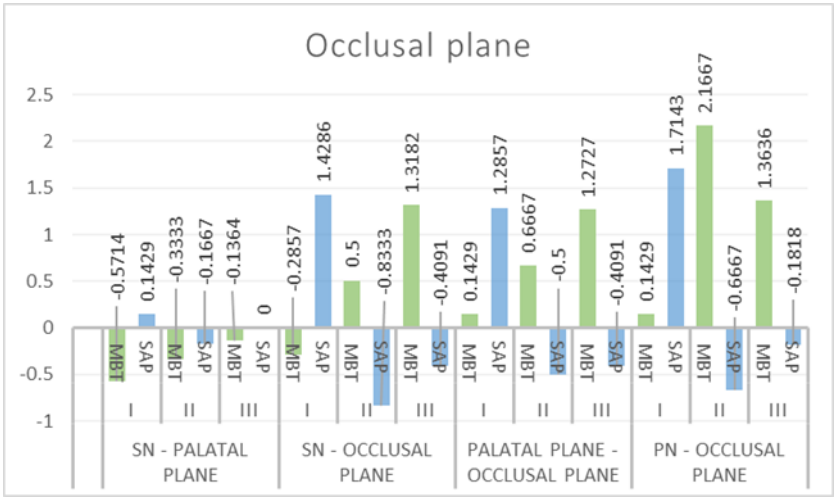
Key Findings:

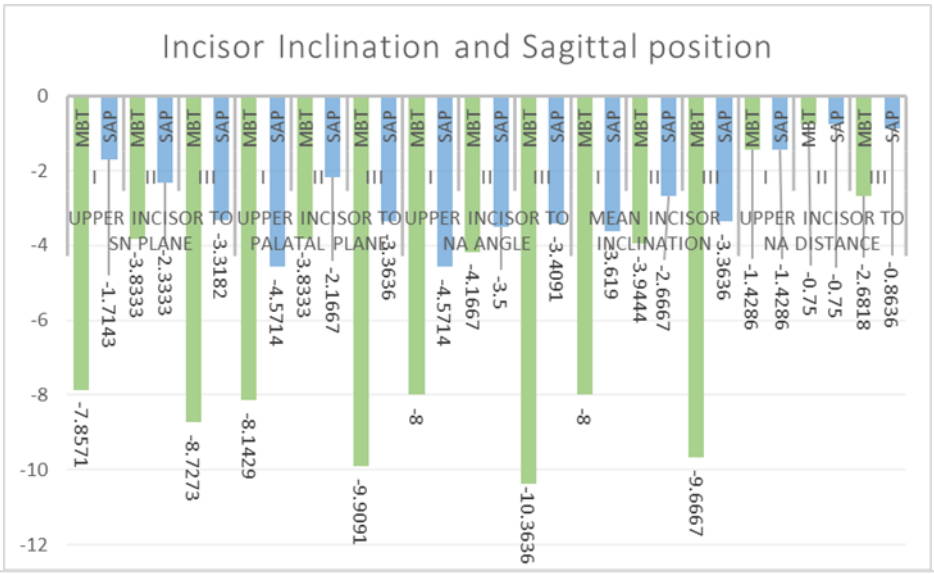
- No significant changes were observed between MBT and SAP groups in SN to Palatal plane angle, Sn to Occlusal plane angle, Palatal plane to Occlusal plane angle, Pn to Occlusal plane angle, Upper incisor to SN plane, UI to Palatal plane, UI to NA angle, UI to NA distance, UI to upper lip, Perpendicular distance from Palatal plane to 1) tip of UI, 2) Anterior most point of CEJ of UI, 3) CR of UI and 4) Furcation of Upper first Molar in both Spacing and Crowding subgroups ($p > 0.5$).
- Well-aligned subgroup showed significant differences in occlusal plane angles, indicating MBT (Sn to Occlusal plane angle ($p = .015$), Palatal plane to Occlusal plane angle ($p = .021$), and Pn to Occlusal plane angle ($p = .029$)) group had greater positive differences.
- Upper incisor angles showed no statistical differences between MBT and SAP groups in Spacing and Crowding subgroups, but significant differences in Well-aligned subgroup favored MBT (Upper incisor to SN plane (p=

.008), Upper incisor to Palatal plane (p=.004), Upper incisor to NA angle (p= .003) and Mean incisor inclination (p=.004)) with greater negative values.

- Significant difference observed in the horizontal distance from NA to Upper incisor (p= .011) in the Well-aligned subgroup, suggesting backward movement of the upper incisor tip in MBT group.
- No significant differences found in parameters Upper incisor to Upper lip, Tip of upper incisor to Palatal plane, CEJ of upper incisor to palatal plane and CR of upper incisor to palatal plane and also furcation of upper molar to palatal plane between preoperative and midoperative values.
- Gingival display significantly increased in SAP group (p= .000) in the Well-aligned subgroup.
- Percentage of consonancy showed significant differences in the Spacing subgroup, favoring SAP (p= .035), while no significant differences were observed in other subgroups.
- No significant differences detected in smile indices between MBT and SAP groups across all subgroups. This proves that if there is any change in smile arc is not influenced by the change in smile display area between the groups.
- No significant differences in preoperative values between MBT and SAP groups for various parameters across all subgroups, validating sample selection.
- Significant changes observed in SI and VSP values from preoperative to midoperative, indicating significant changes in smile display area during a social smile.
- Strong correlations observed between results from survey and delta values of Percentage of Consonancy (p= 0.001), SI (p= 0.001), and VSP (p= <0.001) values and no correlation with MSI values.
- Strong correlations observed between delta values of Percentage of consonancy and MSI (p= 0.024) and high significant correlation with SI (p= 0.003) and VSP (p= 0.006).
- Significant differences noted in parameters Tip of upper incisor to palatal plane (p=0.043) and CEJ of upper incisor to palatal plane (p=0.020) between vertical and horizontal growth patterns and gingival display (p=0.015) between Class I and II skeletal patterns, indicating varying treatment effects.

Graph 1 – Intergroup comparison of differences in preop and midop values of all cephalometric parameters between MBT and SAP group using independent – samples t test. The graph represents mean values of the parameters in Both the groups in Spacing (I), Crowding (II) and Well Aligned (III) subgroups. The graph demonstrates Well-aligned subgroup (III) showing significant differences (p<0.5), with the MBT group exhibiting greater positive differences in certain angles: SN to Occlusal plane angle (Mean = 1.3182 ± 2.27589), Palatal plane to Occlusal plane angle (Mean = 1.2727 ± 2.39408), and Pn to Occlusal plane angle (Mean = 1.3636 ± 2.25822). Conversely, the MBT group showed more negative differences in other measurements: UI to SN plane (Mean = -8.7273 ± 6.95689), Upper incisor to Palatal plane (Mean = -9.9091 ± 8.41715), Upper incisor to NA angle (Mean = -10.3636 ± 8.67698), and Mean incisor inclination (Mean = -9.6667 ± 7.75757). Additionally, a significant difference between the groups was noted in UI to NA distance, with the MBT group displaying a more negative difference (Mean = -2.6818 ± 2.63468) compared to the SAP group (Mean = -0.8636 ± 1.79405). No significant differences were observed in other parameters. These findings underscore the impact of different orthodontic treatment approaches on dental and skeletal alignment outcomes.





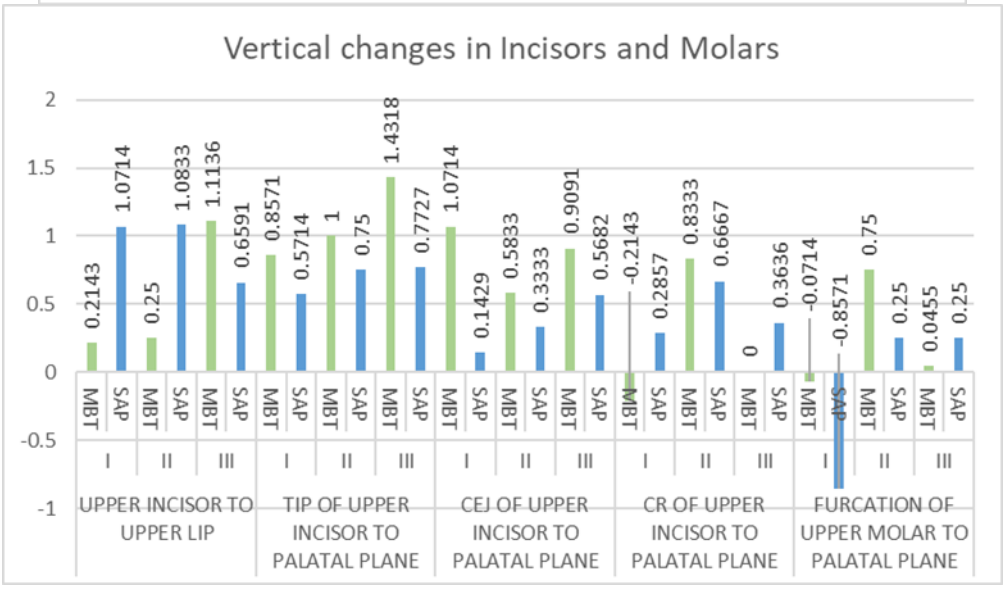


TABLE 1 - Intergroup comparison of differences in preop and midop values of all soft tissue parameters between MBT and SAP group using independent – samples t test. Comparing soft tissue parameters between MBT and SAP groups revealed no significant difference in gingival display changes in the Spacing (p=.685) and Crowding (p=.178) subgroups, but a highly significant difference in the Well Aligned subgroup (p=.000), favouring SAP with greater positive values (.9200 ± .97430). Percentage of consonancy showed significant differences in the Spacing subgroup (p=.035) and no significance in Crowding and Well Aligned subgroups (p=.795, p=.200 respectively), with SAP group showing higher positive values in Spacing (15.0281 ± 19.12752) and Crowding (6.7367 ± 62.01538), while MBT group showed higher values in Well Aligned subgroup (11.2474 ± 24.83007). No significant differences were observed in MSI, SI, and VSP across all subgroups (p > 0.08), indicating no disparity in smile display area changes between the groups.

SOFT TISSUE PARAMETER	SUB GROUPS	GROUPS	MEAN	S.D	SIG	MEAN DIFF
GINGIVAL DISPLAY	SPACING	MBT	.3859	1.38985	.685	-.24257
		SAP	.6284	.67597		
	CROWDING	MBT	-.7450	1.94433	.178	-1.37333
		SAP	.6283	1.26970		
	WELL ALIGNED	**MBT**	**-.9811**	**1.52979**	**.000**	**-1.90114**
		SAP	**.9200**	**.97430**		
MODIFIED SMILE INDEX	SPACING	MBT	.7467	4.33397	.363	1.74195
		SAP	-.9953	2.23645		
	CROWDING	MBT	.2078	2.42918	.469	2.03392
		SAP	-1.8261	6.15652		

	WELL ALIGNED	MBT	.3197	4.24927	.435	.84727
		SAP	-.5276	2.71359		
SMILE INDEX	SPACING	MBT	-.0870	1.87367	.885	-.11753
		SAP	.0306	.96501		
	CROWDING	MBT	-.8515	1.11457	.142	-.92488
		SAP	.0734	.87930		
	WELL ALIGNED	MBT	-.4281	1.35077	.888	-.04374
		SAP	-.3844	.50666		
VSP	SPACING	MBT	.3144	5.23152	.674	-1.08301
		SAP	1.3974	4.11349		
	CROWDING	MBT	4.6323	7.65014	.253	4.85112
		SAP	-.2189	6.12279		
	WELL ALIGNED	MBT	1.5202	6.78546	.088	-3.03222
		SAP	4.5524	4.51337		
PERCENTAGE OF CONSONANCY	**SPACING**	**MBT**	**-12.6023**	**24.12951**	**.035**	**-27.63043**
		SAP	**15.0281**	**19.12752**		
	CROWDING	MBT	-1.4275	41.87232	.795	-8.16417
		SAP	6.7367	62.01538		
	WELL ALIGNED	MBT	11.2474	24.83007	.200	9.57455
		SAP	1.6729	23.94379		

Graph 2 - Graphical representation showing statistically significant parameters in comparison between delta values of soft tissue parameters in MBT and SAP group across the subgroups.

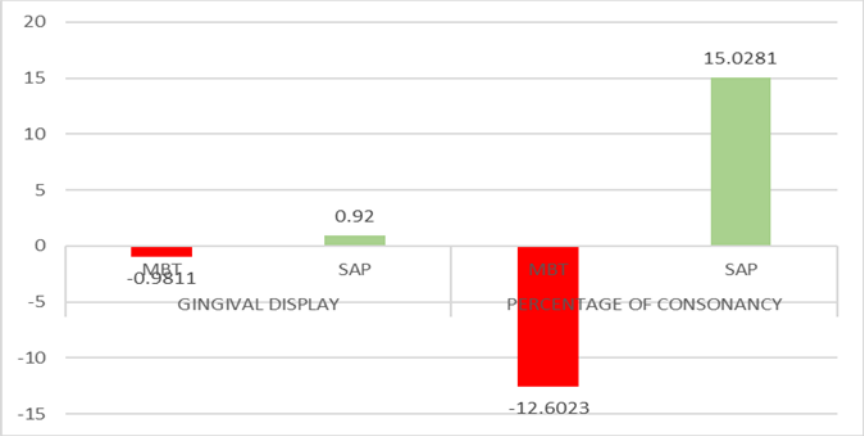


TABLE 2 – Intragroup comparison between preop and midop values of smile indices in the study population using paired t test. Comparing Preop and midop values of MSI, SI and VSP shows that there is statistically no significant change in value of MSI (p= 0.604), significant change in value of SI (p= **0.016, mean diff= 0.328 ± 0.132)** and highly significant change in VSP values (p= **<.001, mean diff= -2.458 ± 0.700)** from preop to midop values. This infers that there is significant change in smile display area in social smile between preop and midop.

Soft tissue Parameter	Time of recording		Statistic	df	p	Mean Difference	SE difference
MSI	Preop	Midop	0.521	69.0	0.604	0.229	0.439
SI	**Preop**	**Midop**	**2.475**	**69.0**	**0.016**	**0.328**	**0.132**
VSP	**Preop**	**Midop**	**-3.511**	**69.0**	**<.001**	**-2.458**	**0.700**

TABLE 3 - Correlation of responses from the survey regarding smile arc with variance in Percentage of consonancy observed between preop and midop stages using spearman correlation. It shows that there is statistically high significant corelation between the variables (p= 0.001, r= 0.403). This infers that Percentage of Consonancy can be used as a reliable parameter for evaluating smile arc.

	SPEARMAN CORRELATION COEFFICIENT TEST	Percentage of Consonancy (DIFF)
SMILE ARC - SURVEY	SPEARMAN'S COEFFICIENT	**0.403****
	SIGNIFICANCE	**0.001**
	N	**62**

**. Correlation is significant at the 0.01 level (2-tailed).

TABLE 4 - Correlation of survey responses on smile display area with variance in smile indices observed between preop and midop stages as well as correlation within those indices using pearson and spearman correlations. It shows that there is statistically no significant corelation with values of MSI (p= 0.728, r= 0.042), high significant negative correlation with values of SI (p= 0.001, r = -0.374) and very high significant correlation with values of VSP (p= <0.001, r= 0.439). This infers that SI and VSP can be used as a reliable parameter for assessing smile display area, with each having their own disadvantages. The correlation analysis between the three smile indices revealed a statistically high significant negative correlation between Smile Index (SI) and both Maxillary Smile Index (MSI) ($p < 0.001$, $r = -0.502$) and Vertical Smile Position (VSP) ($p < 0.001$, $r = -0.733$). However, there was no significant correlation between MSI and VSP ($p = 0.419$), indicating a distinct relationship between each index.

	CORRELATION COEFFICIENT TEST	MODIFIED SMILE INDEX	SMILE INDEX	VSP
SMILE DISPLAY AREA - SURVEY	SPEARMAN'S COEFFICIENT	0.042	**-0.374****	**0.439*****
	SIGNIFICANCE	0.728	**0.001**	**<.001**
	df	68	**68**	**68**
MODIFIED SMILE INDEX	PEARSON CORRELATION	-	**-0.502*****	0.098
	SIGNIFICANCE	-	**<.001**	0.419
	df	-	**68**	68
SMILE INDEX	PEARSON CORRELATION	-	-	**-0.733*****
	SIGNIFICANCE	-	-	**<.001**
	df	-	-	**68**

*Correlation is significant above 0.01 level **. Correlation is significant at the 0.01 level, *** Correlation is significant below 0.001 level (2-tailed).

TABLE 5 - Correlation between percentage of consonancy difference (preop to midop) and smile indices difference (preop to midop) using Pearson correlation showed statistically significant correlation with MSI ($p = 0.024$, $r = -0.270$) and highly significant correlation with SI ($p = 0.003$, $r = 0.353$) and VSP ($p = 0.006$, $r = -0.328$). This suggests that changes in smile display area during a social smile significantly affect smile arc.

	PEARSON CORRELATION COEFFICIENT TEST	MODIFIED SMILE INDEX	SMILE INDEX	VSP
PERCENTAGE OF CONSONANCY	PEARSON CORRELATION	-.270	**.353****	**-.328****
	SIGNIFICANCE	.024	**.003**	**.006**

**. Correlation is significant at the 0.01 level (2-tailed).

Graph 3 - Intergroup comparison of difference in preop and midop values of all cephalometric parameters between different growth pattern using One-Way ANOVA (FISHER'S). Graph represents the mean values of the parameter in three different growth pattern. It showed that differences in preop and midop values of various parameters across different growth patterns, such as Gingival Display, VSP, Percentage of Consonancy, Sn to Palatal Plane, Sn to Occlusal Plane, Mean Incisor Inclination, UI To Na mm, UI To Upper Lip, and Molar to Palatal Plane, showed no statistically significant differences. However, Tip of upper incisor to palatal plane and CEJ of upper incisor to palatal plane exhibited statistically significant differences among the growth patterns (F=3.292; p=0.043 and F=4.138; p=0.020 respectively).

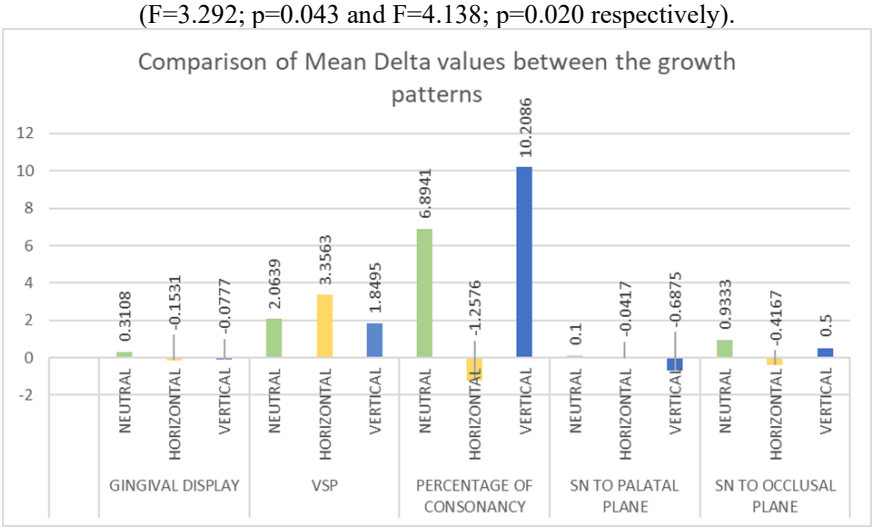


TABLE 6 A. Post hoc analysis revealed a significant difference between Horizontal and Vertical growth patterns for both Tip of upper incisor to palatal plane and CEJ of upper incisor to palatal plane (mean diff= -0.917mm, p=0.035; mean diff= -0.979, p=0.026 respectively), with greater positive values observed in the Vertical growth pattern. This suggests that incisor extrusion is significantly higher in vertical growers during orthodontic treatment. However, there were no significant differences between Horizontal and Neutral or Vertical and Neutral growers. Tukey Post-Hoc Test – Tip Of UI To Palatal Plane.

		NEUTRAL	HORIZONTAL	**VERTICAL**
NEUTRAL	Mean difference	—	0.450	-0.467
	p-value	—	0.310	0.372
HORIZONTAL	Mean difference		—	**-0.917***
	p-value		—	**0.035**

TABLE 6 B. TUKEY POST-HOC TEST – CEJ OF UI TO PLT PLANE

		NEUTRAL	HORIZONTAL	**VERTICAL**
NEUTRAL	Mean difference	—	0.688	-0.292
	p-value	—	0.077	0.687
HORIZONTAL	Mean difference		—	**-0.979***
	p-value		—	**0.026**

Note. * p < .05, ** p < .01, *** p < .001

TABLE 7 - Intergroup comparison of difference in preop and midop values of cephalometric parameters between different skeletal patterns using independent – samples t test revealed statistically significant difference in gingival display (p=0.015), with greater positive values observed in the Class I skeletal pattern (mean = 0.4879±1.293). No other parameter showed statistically significant difference. This implies that Class I patients show increased gingival display during smile compared to Class II patients during orthodontic treatment.

PARAMETERS	GROUPS	MEAN	S.D	SIG	MEAN DIFF	95% CI	
						LOWER	UPPER
GINGIVAL DISPLAY	CLASS I	0.4879	1.293	**0.015**	**0.8750**	0.177	1.573
	CLASS II	-0.387	1.625				
VSP	CLASS I	3.5221	6.020	0.119	2.1909	-0.575	4.956
	CLASS II	1.331	5.547				
PERCENTAGE OF CONSONANCY	CLASS I	5.0154	28.706	0.959	0.3817	-14.343	15.106
	CLASS II	4.634	32.504				
SN TO PALATAL PLANE	CLASS I	-0.0833	0.967	0.720	0.0931	-0.423	0.610
	CLASS II	-0.176	1.193				
SN TO OCCLUSAL PLANE	CLASS I	0.4722	2.990	0.757	0.2075	-1.127	1.542
	CLASS II	0.265	2.574				
MEAN INCISOR INCLINATION	CLASS I	-5.3611	8.436	0.619	0.9526	-2.847	4.753
	CLASS II	-6.314	7.428				
UI TO NA MM	CLASS I	-1.3472	2.299	0.494	0.3734	-0.711	1.458
	CLASS II	-1.721	2.243				
UI TO UPPER LIP	CLASS I	0.8194	1.568	0.900	0.0400	-0.594	0.674
	CLASS II	0.779	1.016				
TIP OF UI TO PLT PLANE	CLASS I	0.9722	1.224	0.921	-0.0278	-0.581	0.526
	CLASS II	1.000	1.087				
MOLAR TO PALATAL PLANE	CLASS I	-0.0833	1.216	0.161	-0.3480	-0.839	0.143
	CLASS II	0.265	0.781				

IV. Discussion

Researches showed that facial attractiveness and dynamic expressiveness were the primary factors influencing the overall perception of attractiveness (Ronald E. Riggio (1991)[20]). According to Joana Godinho et al (2020)[21] the smile accounted for 49% of the variation in the attractiveness of the smiling face in men, while in women, 69% of the variation in facial attractiveness could be attributed to the smile. Various factors can influence the smile aesthetics and one such factor is smile arc. Many researchers concluded that smile arc plays a significant role in influencing smile aesthetics (Vu Pham et al (2021)[22], Parekh et al (2007)[23], A.J. Ker (2008)[24], Burcak Kaya (2013)[25], M. Hulsey (1970)[26], Brisman, A. S. (1980)[27]), while some researchers argues that smile arc doesn't play a significant role in smile aesthetics (Guilherme Janson et al (2011)[28], McNamara et al (2008)[29]). We should aim to achieve a consonant smile arc through orthodontic treatment until influence of smile arc in smile aesthetics is proven otherwise.

Smile arc is invariably affected by orthodontic treatment. Some researchers claims that smile arc is flattened by orthodontic treatment (J.L. Ackerman (1998)[17], Daniel Arrubla-Escobar (2023)[30]); while others state that smile arc is improved by the orthodontic treatment (Anthony L. Maganzini (2014)[31], Christopher Maulik (2007)[32]). David Sarver (2001)[10] advocated bonding upper incisors brackets more gingivally to create a smooth curve of the incisal edges parallel to the lower lip. Tom Pitts (2009)[13] devised a protocol for bonding to create a consonant smile arc called Smile Arc Protection (SAP) bonding protocol. Which was later modified and given as a bracket placement chart by Tom Pitts and Tom castellanos (2014)[16].

- The study group consists of 71.4% Cuspid smiles, 24.3% Monalisa smiles, and 4.3% Complex smiles, diverging notably from prior research.
- Comparison of preoperative to midoperative values for SN to Palatal plane showed no significant differences between MBT and SAP groups across all subgroups.
- Similarly, no significant differences were observed in the steepness of the occlusal plane between MBT and SAP groups, except for a significant clockwise rotation in the occlusal plane in the Well-aligned subgroup of the MBT group.
- The inclination of upper incisors and anteroposterior position of tip of upper incisors were significantly reduced in the MBT group, particularly in the Well-aligned subgroup, indicating increased tipping compared to the SAP group.
- Gingival display significantly increased in the SAP group, notably in the Well-aligned subgroup.
- SAP bonding showed significant enhancement in smile arc, particularly in the Spacing subgroup, while MBT group exhibited improvement in the Well-aligned subgroup which is not statistically significant.
- No significant differences were found in extrusion of incisors between MBT and SAP groups.
- Changes in smile display area over time from survey has significant correlation with SI and VSP, indicating their potential as dynamic measures of smile aesthetics.
- Percentage of consonancy correlated significantly with survey results for smile arc, showing its reliability in evaluating smile aesthetics.
- Smile arc showed significant influence with change in smile display area
- Vertical growers exhibited increased incisor extrusion compared to horizontal growers post-alignment, and Class I patients showed increased gingival display during smile compared to Class II patients.
- Marginal ridge discrepancies were observed between premolars and molars in both MBT and SAP groups post-alignment, suggesting a need for further investigation into bracket placement protocols like SAMRA[33].
- The SAMRA approach[33] and Sarver's[10] advocated differences in incisor dimensions may offer improvements in smile aesthetics but warrant further research for their effects on dentition.

Limitations:

The study's limitations encompass several aspects. Firstly, the smaller sample size within the spacing and crowding subgroups may limit the accuracy and broader applicability of the findings. Secondly, the absence of observation regarding changes in mesiodistal axial inclination between the groups overlooks potential influences from bracket positioning. Thirdly, as the study was conducted post-alignment without full-size SS wires, variations in torque expression due to differing bracket heights were not examined. Moreover, the results obtained from the well-aligned subgroup solely reflect alignment and leveling changes, excluding potential effects post-extraction or retraction. The study also did not consider factors such as compensating curves and incisor morphology, which could impact occlusal plane steepness and incisor inclination changes. Bracket positioning errors commonly encountered in clinical scenarios were not factored in, and the analysis did not delve into variations in smile arc related to demographic or skeletal factors. To gain a comprehensive understanding of SAP bonding's impacts, it's crucial to conduct a double-blinded, randomized controlled trial with standardized covariances and larger sample sizes, incorporating data collection at multiple time points throughout treatment stages.

V. Conclusion

In the well-aligned subgroup, MBT showed reduced upper central incisor inclination, clockwise rotation of the occlusal plane, and more palatal movement of the upper central incisor tip compared to SAP. Gingival display during smile was significantly increased with SAP bonding. In the spacing subgroup, SAP showed significant improvement in smile arc. Overall, there were no significant differences in incisor intrusion/extrusion between groups, and no change in smile display area between preoperative and midoperative stages.

The study validated the reliability of Percentage of Consonancy in evaluating smile arc and highlighted the sensitivity of Smile Indices, particularly the Vertical Smile Window (VSP), in detecting changes in smile display area. Furthermore, the study indicated that smile display area changes over time, with a flattening of the

smile arc observed with increase in smile display area. Additionally, significant incisor extrusion was noted in vertical growers compared to horizontal growers.

In conclusion, SAP bonding can effectively improve smile aesthetics, with attention given to incisor inclination, occlusal plane steepness, and gingival display. Individualized treatment plans should consider these factors along with patients growth pattern and should monitor smile changes during treatment.

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